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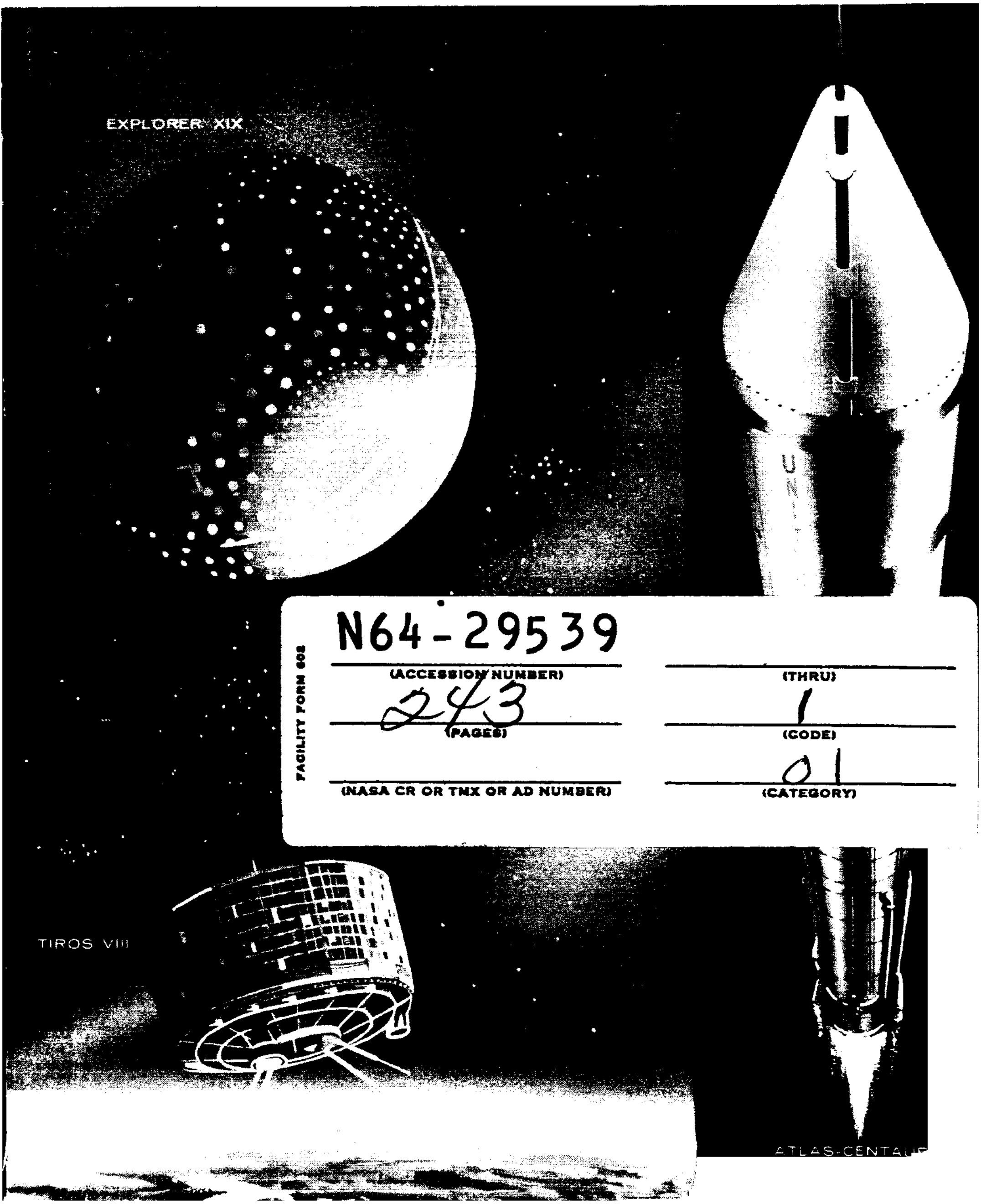
JULY 1 –
DECEMBER 31, 1963

Tenth SEMIANNUAL REPORT TO CONGRESS



Tenth
SEMIANNUAL REPORT TO CONGRESS

JULY 1 - DECEMBER 31, 1963

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D. C. 20546

August 21, 1964

TO THE CONGRESS OF THE UNITED STATES:

Pursuant to the provisions of the National Aeronautics and Space Act of 1958, as amended, I transmit herewith a report of the projects and progress of the National Aeronautics and Space Administration for the six-month period of July 1 through December 31, 1963.

This report reveals in summary and in detail many accomplishments in the national space program. In addition to knowledge-garnering launches and technological developments in this period, NASA has further strengthened the base for greater space progress in the future.

LYNDON B. JOHNSON

THE WHITE HOUSE

August 13, 1964

The President,
The White House

Dear Mr. President: The Tenth Semiannual Report of the National Aeronautics and Space Administration—July 1 through December 31, 1963—is submitted for transmittal to the Congress in accordance with Section 206(a) of the National Aeronautics and Space Act of 1958.

The report is in two parts. The first summarizes progress in NASA programs. The second discusses NASA activities in detail.

NASA celebrated its fifth anniversary on October 1. From Explorer I and Vanguard I, launched in early 1958, through the launchings of 1963, the Nation has succeeded in vastly expanding knowledge and understanding of our own planet earth and of the solar system of which we are a part. Among the major accomplishments of this half year were the following:

a. *Syncom II launched, July 26:* This satellite was placed in the most perfect orbit ever achieved. Its highly successful, internationally tested communications equipment represent an invaluable advance toward a global satellite communications network.

b. *Explorer XVIII launched, November 26:* This Interplanetary Monitoring Probe (IMP) at its farthest point reached 122,800 miles from earth. Its measurements of the major magnetic field phenomena in space provide vital data for developing astronaut shielding material.

c. *Atlas-Centaur launched, November 27:* This was the first successful flight of the high energy liquid hydrogen-liquid oxygen booster (Centaur), a dramatic step forward in developing the more powerful, more efficient boosters of the future. The Centaur was the heaviest payload ever placed in orbit by this Nation.

d. *F-1 engine static fired, December 5:* This was the first static firing of the 1.5 million-pound thrust F-1 engine. The F-1 is to be used in the first stage of Saturn V, the vehicle that will launch men toward the moon.

e. *Exporer XIX launched, December 19:* Launched in a polar orbit, this satellite provided atmospheric density data of the earth's high latitudes. This newer knowledge has great value to future manned and unmanned space investigation.

f. *TIROS VIII launched, December 21:* This satellite featured the first orbiting of the automatic picture transmission system

(APT). When perfected and used aboard a Nimbus, this system will provide pictures of local clouds directly from the satellite to any area in the world by means of a simple, inexpensive ground station.

These achievements and others discussed within the report provide full evidence that the space program is moving forward on a broad front. They fully support my conviction that we are moving to achieve the goals which you, the Congress, and the American people expect of us.

Respectfully yours,

JAMES E. WEBB, *Administrator*

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A Summary

The National Aeronautics and Space Administration continued its efforts to maintain this Nation's preeminence in the overall field of space research and development. During the period of this report, progress was achieved in designing and developing new systems and equipment, in conducting studies related to space understanding and exploration, and in establishing a sound government/industry team to support and assure the success of future space endeavors.

Manned Space Flight

Manned space flight activities progressed with the further development and testing of Project Gemini systems and support equipment; made across-the-board advances in all phases of Project Apollo; and moved to provide the necessary support facilities, services, and supplies.

With Project Gemini, the development work was nearly completed; production, testing, and three 1964 flights were being scheduled; and some hardware was delivered. Testing was completed on the first spacecraft, and its assembly with the launch vehicle was imminent. Spacecraft No. 2 was in the final assembly stages, with virtually all the equipment being delivered, and Spacecraft No. 3 was undergoing the last stages of work. Nos. 4, 5, and 6 were in the early stages of manufacture, and components for the subsequent spacecraft were being made.

Tests for spacecraft systems and components were proceeding on schedule. These included parachute qualification tests, tests of the ejection system and personal parachute, and both static and flotation tests. A significant achievement was the delivery of the first production version of the Gemini's inertial guidance system.

After five months of system functional tests, the first Gemini launch vehicle (GLV) was airlifted to the John F. Kennedy Space Center. The second was in final assembly stages, and components for the third were delivered to the contractor.

The Atlas/Agena target system to be used in Project Gemini was also progressing on schedule. NASA contributed development funds to the Air Force-directed Atlas improvement program. Meanwhile, the Agena modification design work was completed, and development and qualification testing was planned.

Plans were being made for the twelve Gemini missions, with those for the first rendezvous mission (in 1965) being almost completed. Also, 15 astronauts were in training and a new group of 14 was selected.

In the space medicine area, pressure suits, bioinstrumentation, food and waste systems, and personal hygiene equipment were being developed. With some of these—the pressure suit, food and waste systems, for example—fabrication was under way. In connection with this effort, the three military services were giving NASA valuable support.

Project Apollo evolved at an orderly pace, and many of the major facilities were either completed or nearing completion. Reviews of the scheduling revealed that the time/cost relationship was a sound one in light of the scope of the Apollo effort. (Studies of this matter covered other major R&D programs, acceleration versus deceleration of the program, and effects of the space environment.)

Management of the program requires special arrangements since it brings together 14,000 persons in three NASA centers who, in turn, were managing the efforts of some 200,000 people in the contract structure. The Apollo Program Office, Headquarters, was charged with all aspects of overall management. Four field offices were established for major systems management. A NASA-Industry Apollo Executives Group was set up to maintain essential communications between the Agency and major Apollo contractors.

Ground testing of the Apollo boilerplate command and service modules was under way. Tests completed or in process included shipboard rig, rough-water, flotation and handling, and impact. Nine parachute drop tests of the command module boilerplate were made. Also, development of the service module fuel cell and the launch escape system was advancing satisfactorily.

Fabrication was started on the first two Lunar Excursion Module (LEM) test articles for ground development tests, and twelve LEM flight test vehicles for developmental and operational flights were to be delivered. Subsystems and components being tested included the LEM fuel cell and the landing gear. Also, prototype units of the guidance and navigation equipment of the command and lunar excursion modules were undergoing extensive environmental and mechanical tests at MIT.

The Apollo launch vehicles (Saturn I, Saturn IB, and Saturn V) were in various stages of development, testing, and fabrication. The SA–5 vehicle (first Saturn I to be tested with live first and second stages) was delivered to the John F. Kennedy Space Center. Also, the first contractor-produced S–1 (first) stage was completed and accepted by NASA. The seventh S-I stage was static tested, and two additional stages were being assembled.

Qualification testing of the S-IV stage (Saturn I second stage) was completed and the first hot firing of a flight weight stage was conducted. Flight readiness firings of two S-IV stages were successfully accomplished.

Design and development of the S–IB (first stage of Saturn IB) continued, with various component designs (second stage adapter, seal plate, tail section assembly, heat shield) being completed and released for fabrication. The H–I engine (used for both Saturn I and Saturn IB) was improved and uprated to 200,000 pounds of thrust. For the S–IVB (Saturn IB second stage), fabrication of major tooling and the structure for all systems and battleships testing continued on schedule. Also, the J–2 engine for this stage successfully completed a 500-second duration test.

For the Saturn V, initial design of major hardware proceeded on schedule, and the contractor began fabricating components and subsystems for the first all-system stage test. A stable injector for the F–1 engine was developed (engine used with first stage of Saturn V) and production of the engines continued. Also, initial design of the S–II (Saturn V second stage) was completed, and design of other major hardware for this stage moved forward on schedule.

Astronauts began preliminary training for the Apollo flight test program. They took part in the design and development of spacecraft, full-mission simulators, and life support systems. In addition, they began helicopter training, preparing to simulate flight profiles for the lunar landing phase of the mission.

In the Apollo space medicine program, the prototype suit design was completed, fabrication was started, and the first prototype mobility suits were delivered and evaluated. Design of the prototype portable life support systems was completed, fabrication was started, and the first one was delivered to NASA. Also, work continued on various types of bioinstrumentation.

Resources required for Gemini and Apollo development, production, testing, and operations were progressing rapidly. At Marshall Space Flight Center, work went forward on the expansion of one facility and the construction of four others. Also, support facilities were being expanded to support static testing of the Saturn V vehicle. Likewise, the facilities at Manned Spacecraft Center were either completed or moving toward completion. Late in the year, the first contingent of people began occupying some of these. At the John F. Kennedy Space Center, excellent progress was made in constructing Launch Complex 39, the Center's main and support facilities, and the extensive road and utilities systems.

Additional facilities for the design and manufacture of hardware were in various stages of work. Modifications of certain areas of the Michoud plant were complete and construction of other buildings was well under way. At Seal Beach, Calif., the Bulkhead Fabrication Shop was completed and the Vertical Assembly and Hydrostatic Facility were on schedule. Modifications were being made at the facilities of Air Force Plant 16. Other facilities were being prepared at Bethpage, Long Island.

Facilities for development and acceptance testing of both stages and engines were being constructed. These include test stands and related structures at Marshall Space Flight Center, Manned Spacecraft Center, Santa Susana (Calif.), Edwards Air Force Base, White Sands Missile Range, Mississippi Test Facility, and the Merritt Island area at the John F. Kennedy Space Center.

Also at the John F. Kennedy Space Center, work progressed on operational resources. A program was completed to modify the Titan launch pad, Launch Complex 19, for all Gemini spacecraft, and modifications were underway on the old Mercury launch pad to accommodate the Atlas/Agena Gemini target vehicle. Launch Complex 37B was operationally ready to handle Saturn I Block II vehicles.

Further actions were taken to provide the necessary logistics support. A Master Transportation Plan was being prepared to support the lunar landing program. A Boeing B–377 (Stratocruiser) was converted to transport S–IV stages, the Apollo spacecraft, F–1 engines, and other large equipment and was certified by FAA. (Aircraft known as the "Pregnant Guppy.") NASA and the Military Sea Transportation Service (MSTS) signed an agreement providing for ship transportation of Saturn stages. West Coast cryogenic propellant resources were expanded. Steps were being taken to provide liquid oxygen for testing at Mississippi Test Facility, Marshall Space Flight Center, and possibly other East Coast users.

Finally, as part of its overall resources effort, NASA continued to work with and receive valuable assistance from the Department of Defense.

Scientific Investigations in Space

During the last six months of 1963, NASA launched two geophysical satellites—Explorer XVIII, to study radiation and magnetic fields in determining the hazards of manned space flight, and the polka-dotted balloon Explorer XIX, to investigate atmospheric density at an altitude of almost 1,500 miles.

Another milestone in the lunar and interplanetary programs was NASA's selection of a prime contractor for the development of Lunar Orbiter—this country's first satellite of the moon. Orbiter will provide close-up photographs of considerable areas of the moon's surface for exploration and selection of landing sites for unmanned and manned spacecraft.

In addition, a proof test model of a Mariner spacecraft to fly by Mars was assembled. Scientific experiments and principal investigators were selected for the first two Pioneer spacecraft designed to carry 30 pounds of instruments to measure magnetic fields, solar plasma, energetic particles, and other phenomena of interplanetary regions. And components and subsystems were tested for Surveyor. (A far more sophisticated spacecraft than either Mariner or Ranger, Surveyor will soft land on the moon and survey possible sites for later manned landings.)

Also, 40 sounding rockets were launched to carry out experiments in geophysics and astronomy above the earth's atmosphere. Outstanding among these were two instrumented flights to obtain data needed for the planned launching of an artificial comet; and a Canadian flight at about 40,000 feet during the solar eclipse of July 20 to study the effects of the eclipse on ionospheric properties.

The Agency's bioscience program was highlighted by the announcement that the first of its six recoverable biosatellites (orbiting biological laboratories) was planned for launching late in 1965.

In manned space science NASA, cooperating with the Nation's scientists, broadened its programs to include the planning and development of scientific experiments for manned space flights to make maximum use of the astronaut's ability to function in orbit. Further, the Agency has joined the National Academy of Sciences in determining standards for the selection of scientist-astronauts.

(After the close of this report period—July 31—the six TV cameras of Ranger VII photographed the moon just before crashing on the lunar surface. Data provided by these pictures should help pave the way for the soft landings of the Surveyor unmanned spacecraft and the manned lunar explorations of Project Apollo.)

Medium Launch Vehicles

During the report period the Scout, Delta, and Atlas-Centaur medium launch vehicles orbited several spacecraft in NASA's space science and applications programs. In December a Scout launched the Air Density Satellite Explorer XIX. This was the tenth launching by the vehicle and the first time that a NASA spacecraft was launched from the Pacific Missile Range (Point Arguello, Calif.). Delta placed Syncom II, Explorer XVIII, and TIROS VIII in orbit, bringing its total to 21 successes in 22 attempts. Atlas-Centaur, on November 27, was launched from Cape Kennedy in the free world's first successful flight of a liquid hydrogen-fueled vehicle. Its 5-ton payload was placed in earth orbit and the objectives of the flight attained.

Satellite Applications

Marking its eighth consecutive success in launching a meteorological satellite, NASA orbited TIROS VIII in December. This latest TIROS carried the first experimental Automatic Picture Transmission (APT) subsystem as part of extensive qualification tests prior to its being installed aboard the polar-orbiting Nimbus. The APT subsystem is designed to enable meteorologists using relatively simple, inexpensive equipment to receive local cloud cover pictures as the satellite passes overhead.

TIROS VI produced about 60,000 meteorologically-useful TV cloud cover pictures from its September 1962 launching until it stopped transmitting in October 1963. The spacecraft discovered Tropical Storms Hester and Jennifer in 1963 (and Typhoon Karen and Hurricane Arlene in 1962). TIROS VII launched in June 1963 produced 37,183 meteorologically useful pictures in 6 months and discovered 5 hurricanes over the Atlantic Ocean.

The Nimbus prototype, based on knowledge gained from the TIROS flights, was assembled and integrated during the last six months of 1963. Planned as an observatory in space, Nimbus will advance the technology needed to make a fully operational meteorological satellite system possible.

In the field of communications satellites, Relay I operated efficiently beyond its designed one-year lifetime; Telstar II performed with near total success; and Syncom II became the world's first satellite to be placed into synchronous orbit and maneuvered into position.

The second Telstar continued to link Europe with North America, its telemetry channels supplying new data on the space environment. By the end of 1963, Relay I neared 3,000 orbits and linked North America to South America, Europe and Asia, paving the way for early operational systems. In addition, an improved Relay was readied for launch.

Syncom II relayed at synchronous altitude the first multichannel voice communications, multichannel teletype, simultaneous voice and teletype, and facsimile. The spacecraft also set a record for satellite communications—1,575 hours involving more than 5,000 experiments and special tests (as of February 29, 1964). This Syncom also carried voice traffic between Africa and North America which was further transmitted to South America via Relay.

Echo I marked its third anniversary in space on August 12. Its reflective characteristics continued to be monitored, although it is no longer an effective communications satellite. Echo II, an improved rigid sphere 135 feet in diameter weighing 570 pounds, was being readied for launch during this report period. As a result of an agreement on space projects between the United States and the Soviet Union, announced in August, Russian scientists in the U.S.S.R. will use the second Echo to receive radio signals (transmitted via England) in joint communications experiments.

In another development in the satellite communications field, NASA discussed with the ComSat Corp. results of the Agency's experimental programs, and the capabilities of available launch vehicles as they apply to the corporation's plans for its global system.

NASA also investigated the feasibility of a non-military satellite system to serve as an air-sea navigation, rescue, and traffic control aid. Undertaken during this report period, these studies were closely coordinated with those of other Government agencies responsible for the aids and indicated that such a system using simple surface and airborne equipment warranted consideration.

Finally, the Agency used technology developed under the Advanced Syncom project to set up an Advanced Technological Satellites Program. A program objective is to develop and flight-test the advanced technology required to place a stabilized and oriented, long-lived station-keeping spacecraft into 24-hour orbit.

Advanced Research and Technology

In advanced research and technology, efforts included work on light weight, thin film solar cells and on cells more resistant to radiation; on devices to convert high energy to electricity; on solar dynamic systems; and on batteries and fuel cells for space applications.

Work was under way on the effects of high energy electrons and protons on spacecraft materials and components, and construction was begun on a space radiation effects laboratory. Significant information on the penetration of thin metallic surfaces by meteoroids obtained from the Explorer XVI satellite indicated that more information is needed to predict meteorite hazards accurately. For this reason plans were made for more Explorer XVI-type satellites to be launched. Further, plans were made for a larger satellite to be launched by a Saturn booster during Apollo development tests. This will have a larger meteoroid penetration sensing area.

Plans were also made for other experiments to collect data on meteoroids with the ultimate objective of being able to measure the mass of meteoroids seen entering the earth's atmosphere. Tests were made to study the behavior of fluids under zero gravity conditions, and development was continued on devices for automatic control of spacecraft skin temperature. To study launch vehicle heating, a shock tube concept was developed for economical and short duration testing.

In advanced spacecraft research, the initial phase of the M–2 lifting body flight program was completed. This phase proved that lifting body vehicles can be safely flown and landed. Studies were also continued to improve the atmospheric landing and recovery capabilities of existing spacecraft. They showed that it may be possible for spacecraft to be landed at zero impact velocity.

Studies of spacecraft electronics and control indicated that deep space communications could be improved by using optical and submillimeter portions of the frequency spectrum, that laser signals might be utilized, and that more sophisticated modulation techniques might improve the overall efficiency of optical techniques. Research was also initiated to reduce the time required to transfer speech and data information to and from manned spacecraft. And studies were begun of ways to improve the data acquisition capability of ground antennas.

Aerodynamics research included work on reducing airplane drag on supersonic aircraft configurations and on structural fatigue. Studies of fatigue indicated that metals such as columbium and tungsten appeared to be the most practical structural materials for use at hypersonic speeds. Studies also indicated that the X–15 airplane could be used to carry on propulsion research for advanced hypersonic air-breathing propulsion systems. Studies of pneumatic tire hydroplaning produced results of significance to flight safety. (These results were distributed to the aircraft industry, and also to automotive and safety groups because the data can be applied to automobiles.)

The X–15 research airplane program continued to provide data on manned, maneuverable hypersonic flight. The work on modifying the X–15A–2 moved forward and plans were made for the first flight of the modified airplane following the close of the period. The recommendation was made that the X–15 be used to obtain additional research data on air-breathing propulsion, aerodynamics, and structures.

Work also continued on the supersonic commercial air transport. Contracts were let to make detailed, comprehensive engineering design studies of four promising configurations—an arrow wing, a delta wing, and two variable sweep configurations. Results of the studies indicated that a safe, reliable supersonic transport is technically feasible, but that additional research is required. Particularly, it will be necessary to make efforts to reduce the intensity of sonic booms and new and advanced engines will be required. The studies also showed that titanium alloys hold forth great promise as an efficient light weight structure for the Mach 3 transport.

Further studies were also conducted on V/STOL aircraft and on hypersonic aircraft which offer the possibility of a long range earth-to-earth transport system linking cities 5,000 or more miles apart. The hypersonic aircraft may also serve as the reusable first stage of an earth-to-orbit transportation vehicle.

NASA carried on a diversified biotechnology and human research program that included human functions as they relate to aerospace environments, life support and protective systems, and man-system integration. An integrated biomedical sensing and recording system was also being developed.

The Agency continued to improve its advanced nonnuclear propulsion systems. Solid propellant motors would be used in sounding rockets, Scout launch vehicles, Ranger and Surveyor retrorockets, and Syncom I and Advanced Syncom apogee motors. Work with liquid propellant motors included investigations of engines for future launch vehicles, propulsion technology, and propellant storability and sloshing. And a propulsion system for an astronaut spacebelt was being considered.

Basic research in fluid physics sought an understanding of the flow processes of liquid and gas mixtures involved in aircraft, spacecraft, and advanced propulsion systems. Ceramics research resulted in establishing the relationships between the atomic structure, electronic structure, and mechanical strength of crystals of certain ceramic compounds.

Nuclear Propulsion and Power Generation

NASA continued investigating nuclear and electric sources capable of propelling spacecraft in manned explorations of the planets and in extended instrumented probes of deep space. Research also continued into nuclear electric power systems intended to propel lunar stations, orbit platforms in space, and provide power for interplanetary communications.

Key programs in this research and development were the NASA-AEC SNAP-8 project, nuclear electric power research and technology, electric propulsion, and nuclear rockets (Project ROVER.)

The power conversion system of SNAP-8, a compact experimental reactor able to use the heat from the decay of radioisotopes as energy, was redesigned to emphasize state-of-the-art technology and minimize component interdependence. Fabrication and assembly of all major first model power conversion system components neared completion, and the experimental reactor was run at system power and temperature. SNAP-8 is to have a 35-kw nuclear electrical generating system capable of start-up and continuous, unattended operation in space for 10,000 hours. It may power a manned orbital station, a lunar station, manned or unmanned space probes, and communication satellites.

Isotope generators weighing less than SNAP-8 were also under design or development to determine their feasibility for a number of NASA missions.

Objectives of the Agency's electric propulsion (electric rocket engine) program are to develop, test, and evaluate laboratory engine models; provide the technology to develop high-power prime propulsion systems and low-power attitude control and station-keeping engine systems; and investigate advanced concepts.

Electric engines for prime propulsion were being designed to supply up to 30 megawatts of power with a lifetime of 10 to 30 thousand hours. These engines will have a specific weight of 10 to 20 pounds for each kilowatt for manned flight and up to 30 pounds a kilowatt for unmanned flight.

Three general categories of electric propulsion engines were being investigated: electrothermal (arc jet and resistojet); electrostatic (ion); and electromagnetic (plasma or magnetohydrodynamic).

Typical space missions employing these electric propulsion systems during 1967-75 may be: position control of scientific and communications satellites; prime propulsion of unmanned spacecraft, scientific and planetary exploration probes, and lunar supply ferries; and prime propulsion of manned spacecraft.

Noteworthy progress was made in the NASA-AEC program to provide the earliest, most practical use of nuclear rockets in space and the research and technology to support them. These engines were being designed to conduct high energy missions such as extensive lunar exploration, establishment of a base on the moon, and the landing of men on Mars.

By the end of 1963 emphasis in this program shifted to establishing and demonstrating nuclear rocket technology, solving technological problems by operation of nuclear rocket reactors and engine systems, and providing hardware that could lead to flight applications.

For example, several contractors for NERVA (*N*uclear *E*ngine for *R*ocket *V*ehicle *A*pplication) concentrated on developing the reactor and designing and developing critical engine components. Other contractors tested non-nuclear engine components and conducted vibration tests simulating expected vibrations on full-scale reactors.

In developing the basic technology for the first generation nuclear rocket reactor, guidelines were set up for the higher powered advanced graphite reactor program (PHOEBUS) conducted by the AEC.

Tracking and Data Acquisition

NASA's 3 tracking and data acquisition networks supported the successful launch of the liquid hydrogen-fueled Atlas-Centaur and operationally supported 21 satellites of several types.

The Manned Space Flight Network was modified to prepare it for its principal role of acquiring flight data from the two-man Gemini capsule and the Agena Target Vehicle. To meet the special spacecraft requirements of the Ranger lunar flights of 1964, the Deep Space Network also underwent certain modifications. The Agency's Satellite Network was improved by the addition of 85-foot parabolic antennas to support larger and more complex satellites using very wide bandwidths and requiring very high-gain antennas at the ground stations.

International Programs

In its international programs, NASA agreed to new cooperative arrangements with Canada, France, India, Pakistan, and the United Kingdom. The Canadian Defence Research Board signed a Memorandum of Understanding that provides for a joint ionospheric monitoring program. NASA Aerobee rockets were used to launch two French payloads from Wallops Island. And, in a reversal of roles, NASA made plans to fly U.S. payloads on French rockets at a French range. With India and Pakistan, the Agency reached agreements providing for meteorological rockets to be launched over the coming year. Arrangements were also made for the United Kingdom to participate in these experiments.

In August, an Italian crew launched a Shotput sounding rocket from Wallops Island as part of the San Marco project. The following month, a joint NASA-Norwegian-Danish ionospheric payload was successfully launched from the Norwegian range at Andoya. And during July–August, a joint program with Sweden resulted in successful launches of four sounding rockets from Kronogard, Sweden.

Intergovernmental agreements were concluded with Australia, providing for a wide-band command and data acquisition facility to be constructed near Canberra; with Malagasy, for a NASA injection monitoring station near Majunga; with the United Kingdom, for tracking stations in Bermuda and Canton Island; with Canada, for cooperation in testing experimental communications satellites; and with Nigeria, for the USNS *Kingsport* to return to Lagos Harbor to support the Syncom II project.

In Copenhagen on September 14, President Johnson (then Vice President) participated in an exchange of diplomatic notes between the United States and Denmark. These and other notes confirmed a Memorandum of Understanding between NASA and the Scandinavian Committee for Satellite Telecommunication, providing for cooperation in testing experimental communications satellites. And negotiations were initiated with Spain for a tracking and data acquisition station near Madrid.

The international personnel exchange, education, and training programs were continued. Over 1,000 foreign nationals visited NASA facilities. Thirty-six graduate students from 12 countries studied space sciences at 15 American universities.

Fifty-four postdoctoral and senior postdoctoral associates from 18 countries performed research at NASA centers. And 98 technicians from 5 countries and the European Space Research Organization, here at their own expense, received training in space technology at Goddard Space Flight Center, Langley Research Center, and Wallops Station.

University and Basic Research Programs

NASA-sponsored research conducted by universities and nonprofit organizations made possible many of the scientific and technological advances detailed in this report. The Agency relied heavily on universities for fundamental and ground-based research in support of space flight. For example, educational institutions carried on flight experiments with satellites and space probes, and undertook basic studies of high-strength materials for spacecraft.

Basic research in space science and technology was supported by NASA in response to unsolicited research proposals from scientists. In addition, the Agency through its sustaining university program increased university participation in aeronautical and space sciences and engineering, strengthening NASA-sponsored research to best serve the Nation's rapidly accelerating space program.

Informational-Educational Programs

NASA expanded its informational-educational activities and services during the report period. Among key developments were: Establishment of educational services programs at several Agency centers and regional offices; participation with the Defense Department and sponsors of the 1964-65 New York World's Fair in setting up the most impressive collection of full-scale spacecraft and rockets ever assembled outside Cape Kennedy; and testing of a selective information dissemination system which promises to become one of the world's most advanced in the scientific and technical information field.

Personnel, Management, Procurement, and Support Functions

In the personnel field, NASA developed a Management Seminar, a Supervisory Training Program, and a Financial Management Seminar to improve employee effectiveness. It made a survey of its scientific and engineering manpower to find ways of improving its recruitment of these specialists. Overall, the employee complement went from 29,934 to 30,069. Special awards and honors were presented to individuals as well as to groups in recognition of their accomplishments and contributions.

The Inventions and Contributions Board evaluated numerous contributions to NASA and made five awards—three to NASA employees and two to contractor employees. The Board also made a number of recommendations regarding patent waivers; nine such waivers were granted and four were denied.

Major organizational changes were made to consolidate management, to improve program direction, and to provide for more direct lines of responsibility and authority. Changes were extended to the Centers to bring them in line with the Headquarters structure.

Significant steps were taken to further improve the Agency's financial management. These included installation of a new accrual system of accounting, integration of contractor accounting systems with NASA's, a new semiannual reports procedure for industrial facilities and materials in the hands of contractors, an Agency-wide manpower utilization reporting system, and a new reporting system relating to the status of contracts and grants.

In the procurement area, the Agency conducted an Agency-wide procurement conference, issued an industrial property control manual, improved its method of publicizing procurement actions, and issued interim instructions setting forth a new Equal Employment Opportunity clause. The Agency's procurements for the 6 months of this report totaled $1,939 million. About 95 percent of this total was contracted to private industry, much of which went to small business. Prime contracts were distributed among 43 States and the District of Columbia.

The technology utilization program placed emphasis on encouraging contractors to report new ideas and processes emerging from their performance. The Agency developed a new technology clause that will be added to all new NASA contracts and to existing ones when renewed. The program also continued its efforts to find even better ways of evaluating new technology and disseminating this information to industry.

Activities and Accomplishments—

The Details

Manned Space Flight

The July–December 1963 period was one of great and growing activity in the manned space flight program. Steady progress was made in the Gemini, Apollo, Advanced Manned Missions, and supporting programs. It was a period of "filling the pipeline"—moving from design and manufacture to the actual delivery of hardware and the intensification of testing. It was a period of rapid and orderly buildup of effort in construction of hardware and facilities, and the marshalling of industry and personnel—when the groundwork was being laid for very substantial advances in national space capability which will be demonstrated during the later test and operational phases.

Manufacture of ground and flight hardware accelerated, as did also the buildup of the required Government-industry team of thousands of engineers and scientists and supporting personnel throughout the United States. In supporting facilities, the peak had already been passed in construction for the Apollo program. Many large and vital installations had been constructed and some were in use. During the reporting period, others were being constructed or nearing completion.

Steady progress was made in furthering and planning for all manned space programs—the two-man, earth orbital, rendezvous-docking Gemini program; the earth orbital and lunar flights of the Apollo program; and the further penetration of space represented in Advanced Manned Missions beyond Apollo. In Gemini, the design phase was passed, the manufacturing phase advanced to its final stages, and efforts intensified in planning and preparations for the first flights, in 1964.

In Apollo, the first phase of the Saturn I launch vehicle program was successfully completed; and preparations were well advanced toward the beginning of the second phase, in which the full two-stage vehicle would be given orbital flight tests. The spacecraft passed through the design phase, and some of the early testing for pilot safety was conducted. In Advanced Manned Missions, planning of Apollo activities was broadened.

A significant development during the reporting period was a major realignment of Manned Space Flight as part of an overall NASA reorganization. This reorganization resulted in decentralization of some management functions to the Field Centers, a tightening in the management structure of the Gemini and Apollo programs, and the establishment of a capability for the institutional administration of the three Manned Space Flight Field Centers.

All told, during the July–December 1963 period another major advance was made in manned space flight toward the national objectives in space, achievement of which will permit the Nation a freedom of choice to carry out whatever missions the national interest may require—be they for national prestige, military requirements, scientific knowledge, or other purposes. A major step was taken toward insuring U. S. leadership in space and demonstrating that preeminence clearly to the world.

Management

An extensive realignment of the management structure was accomplished on November 1 as part of a NASA reorganization. In the new organization, the Associate Administrator for Manned Space Flight continued to be charged with the integrated management and administration of manned space flight programs and the institutional resources required to accomplish those programs, including the development, manufacture, and testing of manned spacecraft and large launch vehicles; training of ground and flight crews; operational control of manned space flight missions; conduct of manned scientific investigations in space; and the planning, budgeting, and management of all these activities.

The new management structure provided for both institutional and program management of the Centers. The organization was divided fundamentally into three levels which report to the Associate Administrator for Manned Space Flight.

On the first level is that group of staff activities related to planning, developing, and implementing the basic capabilities of the three Field Centers and the Washington office. It also includes the groups that provide support for program management and assist in the conduct of institutional administration and internal and external relations.

On a second level are three program offices for the overall direction of the Gemini, Apollo, and Advanced Manned Missions programs. On the third level are the three Manned Space Flight Field Centers: Manned Spacecraft Center, Houston, Tex.; John F. Kennedy Space Center, Cocoa Beach, Fla.; and the George C. Marshall Space Flight Center, Huntsville, Ala. (On November 28, 1963, President Johnson, in his Thanksgiving message to the Nation, announced his intention to rename the space facilities at Cape Canaveral, as well as the Cape itself, in honor of the late President Kennedy. The action was accomplished by Executive Order on November 29. Accordingly, NASA redesignated the Launch Operations Center, Cocoa Beach, Fla., the John F. Kennedy Space Center.)

Concurrently with the reorganization of the Manned Space Flight Headquarters, the three Field Centers began to align their organizations with Headquarters. Under the new organization, each Center was organized into two major line groupings, one having responsibility for marshalling the vast efforts of industry in the various programs. The other one focuses the hardware efforts within the NASA organization and provides for the management of such major development efforts as launch vehicle stages, spacecraft modules, ground installations, and so on within the overall boundaries established by the program offices in Washington.

The new organization resulted in maximum delegation of responsibility and authority to the three Field Centers, which were organized on the project office concept. The basic philosophy of this concept is that a single full-time individual is responsible for each of the major systems in the program. The Program Director in Washington is responsible for the overall program. The project office organizations for the Gemini and Apollo programs are discussed below under the respective programs.

The Gemini Program

The Gemini program moved ahead on many fronts during the last half of 1963, as the final groundwork was laid for the first flights, scheduled in 1964. Technological advancements required to achieve program objectives were made.

The management structure was tightened as part of the overall reorganization of NASA and Manned Space Flight. And Gemini became an essential in an enterprise important to the national defense because of the support it would provide to the Air Force Manned Orbiting Laboratory (MOL)—announced in December.

Objectives

The Gemini program is the second major step by the United States in manned space systems development and space exploration. It follows the pioneer efforts in Mercury and prepares the way for Apollo. Two-men earth orbital flights early in the program will lead to long-duration flights and rendezvous-docking flights in later phases.

The basic objectives of Gemini are to increase the operational proficiency and knowledge of the technology of manned space flight. Two major mission objectives have been established. One is long-duration flight, up to 2 weeks—longer than required for an Apollo lunar mission. The second is to achieve and become proficient in rendezvous and docking operations—during which the spacecraft and a target vehicle will be joined while in orbit.

Associated operational objectives include: Maneuvering in space after docking; performing controlled reentry; conducting extravehicular activities; landing at a preselected site; and accomplishing a number of scientific experiments sponsored by NASA, the Department of Defense, and the scientific community.

Knowledge gained during Gemini flight missions will contribute substantially to future Apollo operations. For example, Gemini will first use the controlled reentry technique which will pave the way for later controlled reentries in the Apollo program. In Gemini, astronaut exit from the spacecraft in orbit can be demonstrated for the first time.

An important aspect of Gemini is that the astronauts and ground personnel will be trained in missions more complex than those of Mercury, in which about 54 hours of manned flight experience was gained. In fact, the team that will later be employed in the Apollo program will receive extensive training in Gemini. For example, prior to the first manned earth orbital flight of Apollo, Gemini will have accomplished many hundreds of hours of manned flight, including three long-duration and six rendezvous missions.

In the area of flight missions and training, Gemini missions will include essentially every technique of the rendezvous maneuver to be used in Apollo. Gemini will also have the flexibility to perform rendezvous missions in many different ways, thus providing the experience needed to develop optimum techniques for Apollo.

The experience to be gained in checkout and in preflight operations is also important. During the Gemini program, for instance, operational personnel will gain experience with many new and complex systems. In learning how to check out the Gemini spacecraft—with its guidance system, its propellants, and its fuel cells—time and experience will be gained for the Apollo program, which will employ similar systems.

Finally, in the area of ground support, the same mission control center and parts of the same network will be used in Gemini and Apollo. In Gemini, as in Apollo, pulse code modulation, telemetry digital data links, and similar or identical ground displays will be used.

Some of the potentialities of Gemini—although they were not an established part of Gemini program objectives in the last half of 1963—are interesting to note. These include the study of future space operations, such as rendezvous of spacecraft with orbiting space stations, inspection of unmanned satellites, and other flight research activities.

For example, the Department of Defense (DOD) on December 10, 1963, announced its decision to assign to the Air Force development of a near-earth Manned Orbiting Laboratory (MOL). All the technological and operational knowledge and experience gained in Gemini by NASA will contribute directly to the MOL, which will use modified Gemini spacecraft and flight hardware.

Management

The development-management structure for Gemini is similar to that used in Project Mercury. However, it was strengthened in the November reorganization, when the Gemini Program Office was established.

Gemini Program Planning Board.—Management of the Gemini program is coordinated at the policy level by the Gemini Program Planning Board (GPPB). This Board was established by NASA/DOD agreement in January 1963 to coordinate and implement Department of Defense participation in the Gemini program. Cochairmen of the Board are the Associate Administrator of NASA and the Under Secretary of the Air Force.

The Board continued to meet monthly in the last half of 1963, coordinating policies and resolving top-level NASA/DOD problems in the Gemini program. It was instrumental in establishing the DOD Experiments Program to be carried out on Gemini flights and the Air Force Titan II Engine Improvement Program, undertaken to make sure that the launch vehicle has the required reliability for NASA's manned application.

Gemini Management Panel.—An additional mechanism for top-level management review, the Gemini Management Panel, established near the end of 1962, continued to meet every 6 weeks and review critical problem areas. Members of this Panel, which functions as a "board of directors" for the Gemini program, represent top-level representatives of all the principal Government and contractor organizations participating in the program.

Program Management.—The Gemini Program Director, Manned Space Flight Headquarters, is responsible for the overall day-to-day management of the program. The Gemini Program Manager at the Manned Spacecraft Center (MSC) is responsible for hardware development, including the spacecraft and associated equipment and the launch and target vehicles.

MSC contracts with a private corporation for spacecraft development and through the Space Systems Division/Air Force (SSD/AF) for development of the launch vehicle and the Atlas-Agena target vehicle. NASA, the SSD/AF, and the vehicle contractor continued to work closely during the July–December 1963 period on all aspects of the program. Representatives from the Manned Spacecraft Center Gemini Program Office, the Air Force, and the contractors met approximately every 2 weeks to work out problems and to effect decisions.

Development and Testing

During the period, most of the Gemini development was completed. Steps were taken to prepare for the production, testing, and the three flights which were scheduled for 1964 (the last one being manned and orbital). (The Gemini program can feasibility; 1962—design; 1963—development; 1964—production, broadly be categorized by calendar years as follows: 1961—test, initial flights; 1965 and 1966—production and operational flight missions.)

Significant hardware deliveries included flight spacecraft No. 1 and No. 1A, launch vehicle No. 1, seven nonflight spacecraft, and a considerable amount of testing and training equipment.

Gemini flight systems consist of the Gemini spacecraft, a modified Titan II launch vehicle, an Agena target vehicle, and an Atlas booster.

Spacecraft.—The two-man Gemini spacecraft is the successor to the Mercury spacecraft and draws heavily on proven Mercury technology. However, it is also far more advanced, complex, and versatile and will provide a transition from the pioneering achievements of Mercury to the lunar program of Apollo. It is larger than that used in Mercury and is divided into three basic sections: Reentry, retrograde, and equipment adapter. (See fig. 1–1.)

Modularized equipment is located in a series of equipment bays around the pressurized cabin to provide for accessibility during testing and checkout and for ease of replacement. Access doors and external check points are provided for use by the launch crew to quickly locate and service a faulty item.

New subsystems were introduced: Fuel cells to replace batteries; ejection seats; on-board spacecraft propulsion for maneuvering in space; and a rendezvous radar and an inertial guidance system for rendezvous with the Agena. (The inertial guidance system also provides backup guidance capability during launch to the Gemini launch vehicle's primary guidance system.)

The contractor will supply 12 flight spacecraft and 10 non-

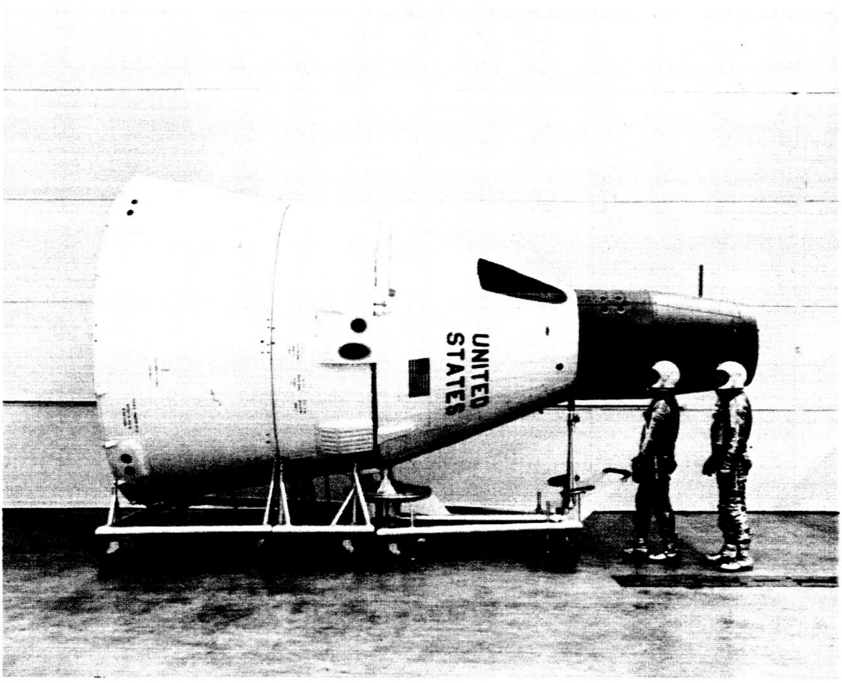


Figure 1–1. Mock-up of Gemini spacecraft.

flying spacecraft for use in development and qualification testing of subsystems and for various spacecraft structural, thermal, and recovery tests. All of the nonflying spacecraft had been manufactured and were in various test phases in the last half of 1963.

Spacecraft scheduled for flights in the qualification phase of the Gemini flight schedule underwent significant development during the reporting period. The qualification phase consists of the first three missions, which will prove out equipment and lay the foundation for later, more difficult missions in the operation phases of the flight program.

Spacecraft No. 1, for flight No. 1, an unmanned orbital flight, was delivered to the John F. Kennedy Space Center on October 4 after extensive tests at the contractor's plant. (See fig. 1–2.) At the end of the year, testing was completed and the spacecraft was awaiting assembly with the first launch vehicle on Launch Complex 19.

A boilerplate spacecraft (No. 1A) was delivered to the John F. Kennedy Space Center on December 15 for use as a backup in the event No. 1 does not provide the necessary flight information.

Spacecraft No. 2 is scheduled for mission No. 2. This is an unmanned suborbital mission designed to qualify the heat shield and recovery systems, while providing an environmental check on the equipment to be flown in mission No. 3, the first manned flight.

In July the spacecraft was ready for the final stages of assembly. Work on the spacecraft advanced to the stage in which tests of the major modules could be begun in preparation for launch.

All equipment for spacecraft No. 2 had been delivered by the end of 1963 except for the experimental fuel cell. Spacecraft No. 2 was to carry the cell to test the zero "g" effects on the fuel cells. It is anticipated that the fuel cell will be available for long-duration Gemini missions.

Spacecraft No. 3, intended for mission No. 3, the first manned mission of the Gemini program, also began undergoing final stages of work—such as equipment installation, incorporation of engineering changes, cold plate installations, shingles fitting, and hatch rigging. Fabrication and installation of wire bundles and plumbing were also started.

Spacecraft Nos. 4, 5, and 6 had reached early stages of manufacture and fabrication by the end of the year. Components of subsequent spacecraft were also being fabricated.

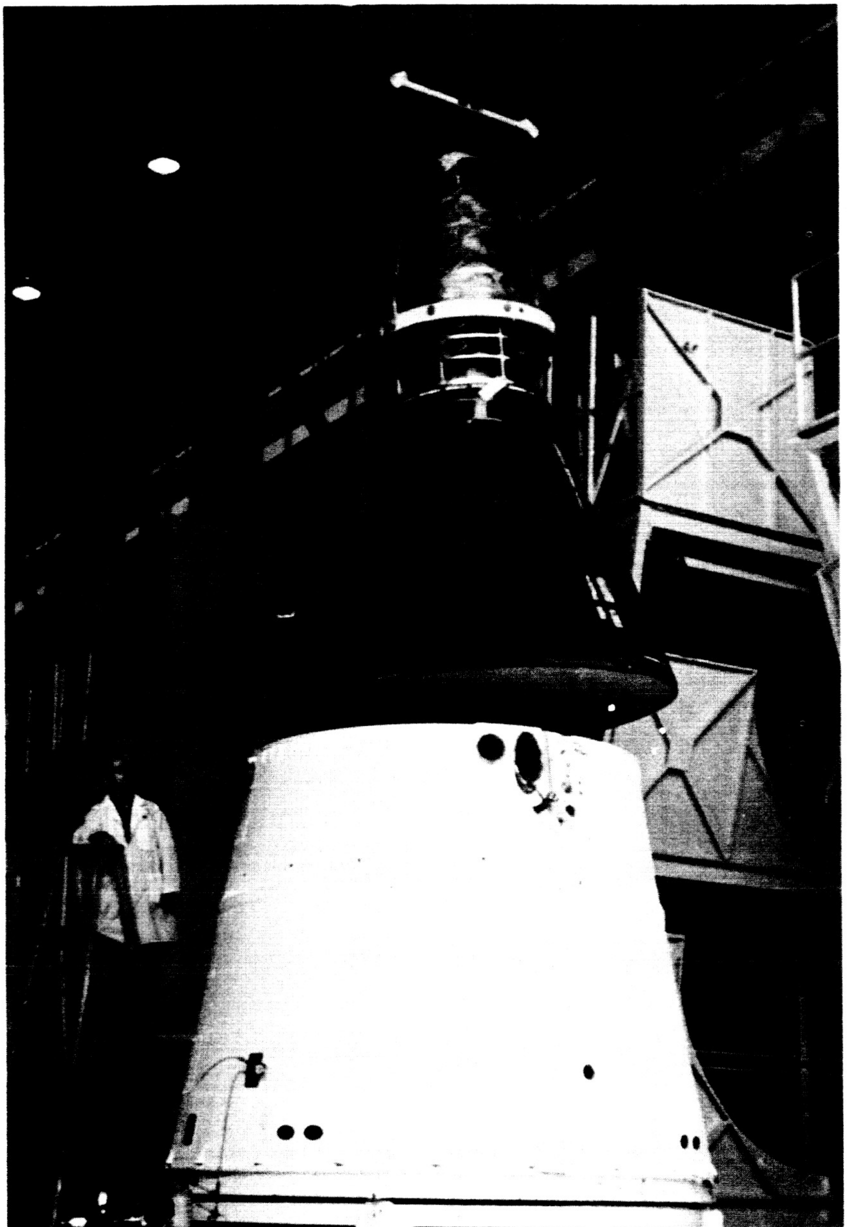


Figure 1–2. Gemini spacecraft at the John F. Kennedy Space Center.

In the test program for the various spacecraft equipment components and subsystems, major effort was devoted to the structure, recovery, and ejection seat systems. Spacecraft parachute qualification tests were successfully conducted; these included two landings in the Salton Sea to determine water reentry characteristics.

Tests of the ejection system and personal parachute, using a dummy, were successfully completed in the summer at the sled test facility of the Naval Ordnance Test Station, China Lake, Calif.

A significant milestone was reached on November 15, when the first production version of the inertial guidance system developed for Gemini was delivered. This represented the first use of an inertial guidance system in the manned space flight program.

Static tests continued at several installations during the last half of 1963. The Manned Spacecraft Center initiated an analytical investigation of the structural integrity of the spacecraft-launch vehicle interface structure. During July, tests of the ability of the spacecraft structure to withstand the ultimate parachute load and the critical off-angle parachute load were carried out with satisfactory results.

Static tests of reentry module reaction to parachute release loads and of landing gear behavior under various landing loads were also completed in July. The adapter was subjected to static loads simulating retrorocket loads and to launch and abort inertial loads. Equipment modules were subjected to ultimate boost and lateral loads, such as might occur during abort. The test articles withstood these ultimate loads satisfactorily.

A spacecraft for flotation tests was completed, put through calm-water flotation tests at the contractor's plant, modified to the latest spacecraft configuration, and shipped to the Manned Spacecraft Center. There, it was to undergo further flotation and egress tests.

In Los Angeles, the Gemini environmental control system contained in a spacecraft cabin mockup was subjected to development testing under simulated space conditions in a vacuum chamber. The system had already undergone component development and system development testing. At the end of the year, 7 months of qualification testing had been completed.

Many other test articles were manufactured and many other tests were formulated during the July–December 1963 period, one of intensive development, qualification, reliability, and systems testing.

Launch Vehicles.—The Gemini launch vehicle is a Titan II ICBM booster modified for greater reliability and astronaut safety. Safety modifications include: redundant electrical power and flight control systems; a malfunction detection system to warn the astronauts of launch vehicle failure requiring abort; replacement of the Titan II inertial guidance system with the radio guidance system used successfully in Project Mercury; and removal of items useful only to the Titan II missile.

NASA is procuring fifteen Gemini launch vehicles through the Air Force Space Systems Division. The Air Force, in turn, is carrying out this procurement program under five major contracts: For the launch vehicle, the engines, the guidance system, the computer, and technical assistance.

The first Gemini launch vehicle was airlifted to the John F. Kennedy Space Center on October 26, 1963, following 5 months of system functional tests at the contractor's plant in the Vertical Test Facility, using ground test equipment similar to that used at the launch site. (See fig. 1–3). Further comprehensive tests at Launch Complex 19 were begun to establish compatibility with the complex and to verify flight readiness. (All Gemini flights will utilize Launch Complex 19, a Titan I launch complex that has been modified for the first Gemini launch.)

The second launch vehicle was in the final stages of assembly at the contractor's plant. Some of the components for launch vehicle No. 3 were delivered to the contractor for assembly and test.

The Gemini launch vehicle development and ground testing program continued to derive valuable complementary benefits from the Air Force Titan II flight testing program. The Air Force program provided invaluable launch operations experience and actual space flight test data directly applicable to the Gemini launch vehicle.

The malfunction detection system, by which astronauts are alerted to launch-vehicle malfunctions, was flight tested in August on an Air Force Titan II.

Atlas/Agena Target System.—The complete Gemini target system, to be used in rendezvous and docking, consists of a modified Agena D and an Atlas standard launch vehicle. Eight Atlas/Agena target vehicle systems were being procured through the Air Force Space Systems Division. The Agena target vehicles will be launched from modified Launch Complex 14, the one

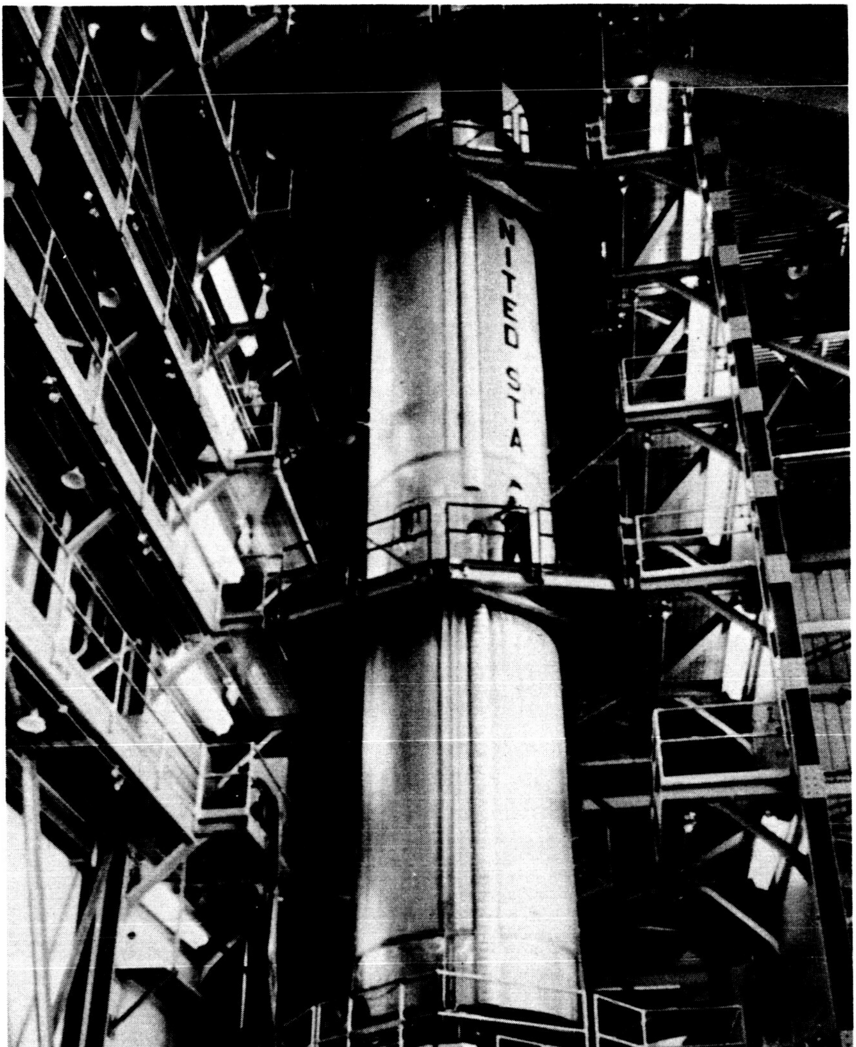


Figure 1–3. Gemini launch vehicle in Vertical Test Facility.

used for the Project Mercury flights. The modifications comprise new instrumentation and cabling for the Agena and a new fuel-loading facility for the Atlas standard launch vehicle.

Atlas.—The Atlas standard launch vehicle was being further improved by the Air Force to increase reliability and flexibility during count-down and launch. NASA is contributing development funds to the improvement program.

Agena.—The modifications to the basic Agena D, to make it a target vehicle, will provide for additional maneuverability in orbit; for command and communications compatible with the Gemini spacecraft and the ground station network; and for docking with the spacecraft.

These modifications consist of changes in the electrical power and telemetry systems; in the spacecraft command recorder and decoder subsystems; in major modifications in the propulsion system; and in addition of the docking adapter and shroud.

The main engine was given a multiple restart capability so that it may be started as many as five times in orbit for rendezvous and post-rendezvous maneuvers. A secondary propulsion system was also being added to provide small velocity changes and propellant orientation for main engine start.

The Agena development is not as far along as that of the Gemini spacecraft and the launch vehicle because the Agena is not required in the program until the first rendezvous flight in 1965. The Agena modification design work was finished in 1963, and development and qualification testing were planned for completion in 1964.

The Agena main engine tests were successfully completed in July 1963 at Arnold Engineering Development Center under a simulated space environment to confirm the structural integrity of the nozzle extension during multiple engine starts. Several other tests of Agena systems were carried out during the reporting period, including separation tests of the Gemini-Agena shroud, and design proof tests on the telemetry and several units of the command and control system.

Mission Planning

At the end of 1963, plans for the 12 Gemini flight missions were being formulated. Detailed operational planning was completed for the first mission and was well along for the second and third.

Mission designations for the Gemini flight program were adopted during the period. Nonrendezvous flights were designated "G" for Gemini and "T" for Titan. Thus the first flight was designated GT-1. Because the Agena target vehicle was identified by "A", rendezvous missions involving the launch of the Gemini-Titan and the Agena vehicle would be itentified as "GTA".

Gemini mission planning was coordinated by monthly panel meetings at the Manned Spacecraft Center. Mission documentation was organized for program instrumentation, program requirements, operations requirements, data acquisition plans, mission rules, flight plans, and mission directives.

Spacecraft launch abort ground rules were developed, and abort boundaries were being refined. Tentative ground rules for Agena maneuvering procedures were also developed, and Gemini launch window studies for rendezvous missions were completed. Planning for the first rendezvous mission in 1965 was almost complete. The Mission Control Center and the tracking network were ready to support the first mission. Specifications of ground support requirements for control, tracking, and data acquisition on later missions were also nearly completed.

Astronaut Training

At the end of the period, 15 astronauts were in training. In addition, during the fall a new group of 14 was selected. They were scheduled to report and begin training in January of 1964, bringing the total to 29 in training for Gemini and Apollo missions. Consideration was also given to the future selection of scientist-astronauts, a program to be conducted with the assistance of the National Academy of Sciences.

The astronauts in training during the period completed their general Gemini training, including academic instruction; water, jungle, and desert survival; parachute landing practice; zero-gravity indoctrination; systems briefing; and flights in high-performance aircraft. Jungle and desert survival training were conducted under the auspices of the Air Force in Panama and at Stead Air Force Base, Nev., respectively. Water survival training was conducted at the Manned Spacecraft Center and at the Navy facility at Pensacola, Fla. Parachute landing training was conducted at the Manned Spacecraft Center. (See fig. 1-4.)

The new environmental training included indoctrination in

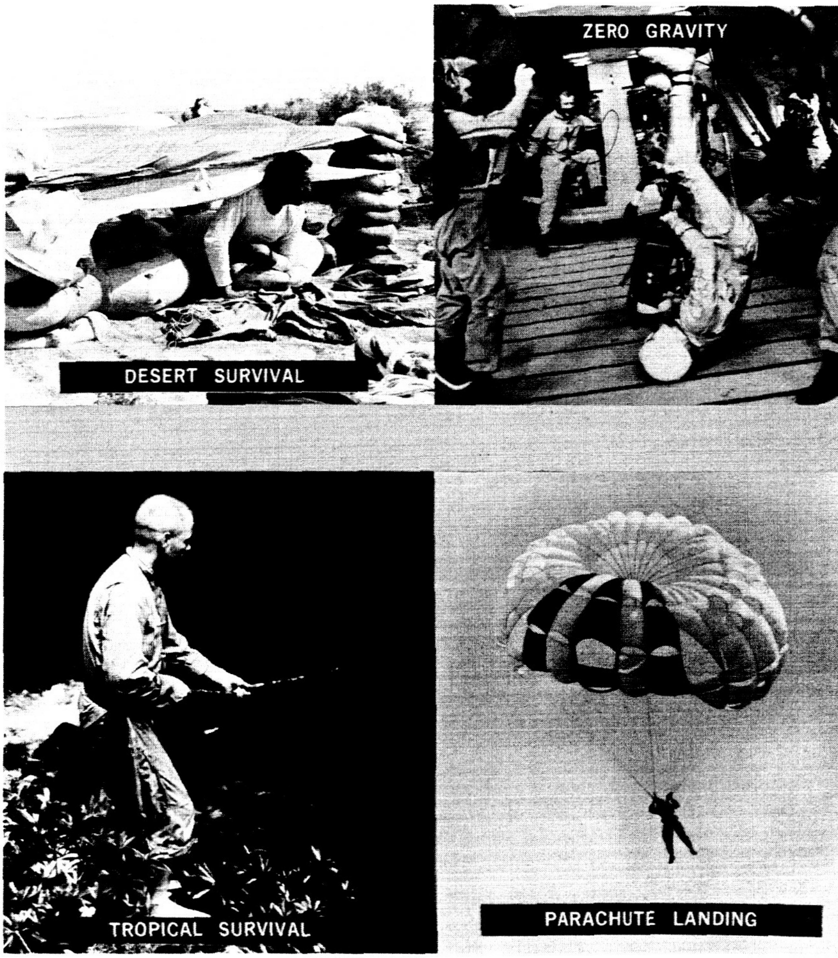


Figure 1–4. Astronaut training activities.

high-g and zero-g environments, as well as indoctrination in life support systems, such as an astronaut's space suit.

The astronauts also participated in space vehicle development. For example, they conducted an engineering evaluation of a replica of the spacecraft crew station installed on a centrifuge. Under realistic simulation of the accelerations of boost, abort, and reentry, the controls, displays, seat, pressure suit, and restraint system were tested. Improvements in controls and displays evolved from the astronauts' recommendations.

Mockup spacecraft reviews were held throughout the reporting period. These reviews allowed detailed inspection and simulated operation in the cockpit by the astronauts and flight crew support personnel. Many recommendations for alteration resulted.

A moving base docking trainer was in the final assembly phase at the contractor's plant and was soon to be operational at the Manned Spacecraft Center for dynamic simulation of the docking maneuver. The first of the two Gemini Mission Simulators was fabricated and shipped to the Mission Control Center at Cape Kennedy. The second trainer, to be installed at the Manned Spacecraft Center, was still being fabricated. The two trainers would allow simulated conduct of full Gemini missions. Systems trainers for all the major spacecraft subsystems were delivered to the Manned Spacecraft Center early in the reporting period, and all astronauts were trained with them. (See fig. 1–5.)

During the last half of 1963, crew integration efforts were directed toward developing qualified crews for Gemini flights. Primary and backup crew members for the first manned flights were scheduled to be selected in 1964.

Figure 1–5. Gemini mission simulator.

Aerospace Medicine

In the field of space medicine, various steps were undertaken during the reporting period to insure the safety of the Gemini astronauts and to provide the equipment and material necessary for the performance of their mission assignments.

These included the development of pressure suits, bioinstrumentation, food and waste systems, and personal hygiene equipment. Various test studies were being made to evaluate the suitability of flight crew equipment and to establish medical controls.

The protoype full pressure suit (fig. 1–6) was fabricated and evaluated in 1963. A training suit was also designed, and fabrication was begun.

Bioinstrumentation for Gemini flights will comprise an oral thermometer, an impedance pneumograph, and a blood-pressure measuring system. During the period, work on signal amplifiers for these instruments was begun; a prototype miniature biomedical recording system was developed; integration of this recorder with the electroencephalograph was initiated; and a number of minimum operational criteria were identified for monitoring extravehicular activity.

Food, water, and waste systems are highly important to the Gemini long-duration missions. Work was carried on to extend the number of menu items and to advance packaging techniques for dehydrated foods. Gemini food consists mainly of freeze-dried foods requiring only reconstitution with water before eating. Also, during 1963, both the drinking water system and the urine transport system were designed, and fabrication of flight hardware for both systems was started.

One further example of space medicine activity is that of control medical studies of the stresses the astronauts will encounter in space flight. Bed-rest studies simulating weightlessness were begun at the Texas Institute of Research and Rehabilitation, and work on the tests of expenditure of energy in a pressurized space suit were initiated at the Air Force School of Aviation Medicine. These and other Gemini studies also have application to the Apollo flights.

A major accomplishment during the reporting period was the development and implementation of program coordination procedures with the Air Force (USAF)—for the Gemini, as well as the Apollo and other programs. By joint agreement, the USAF bioastronautics and NASA space medicine fiscal year 1964 pro-

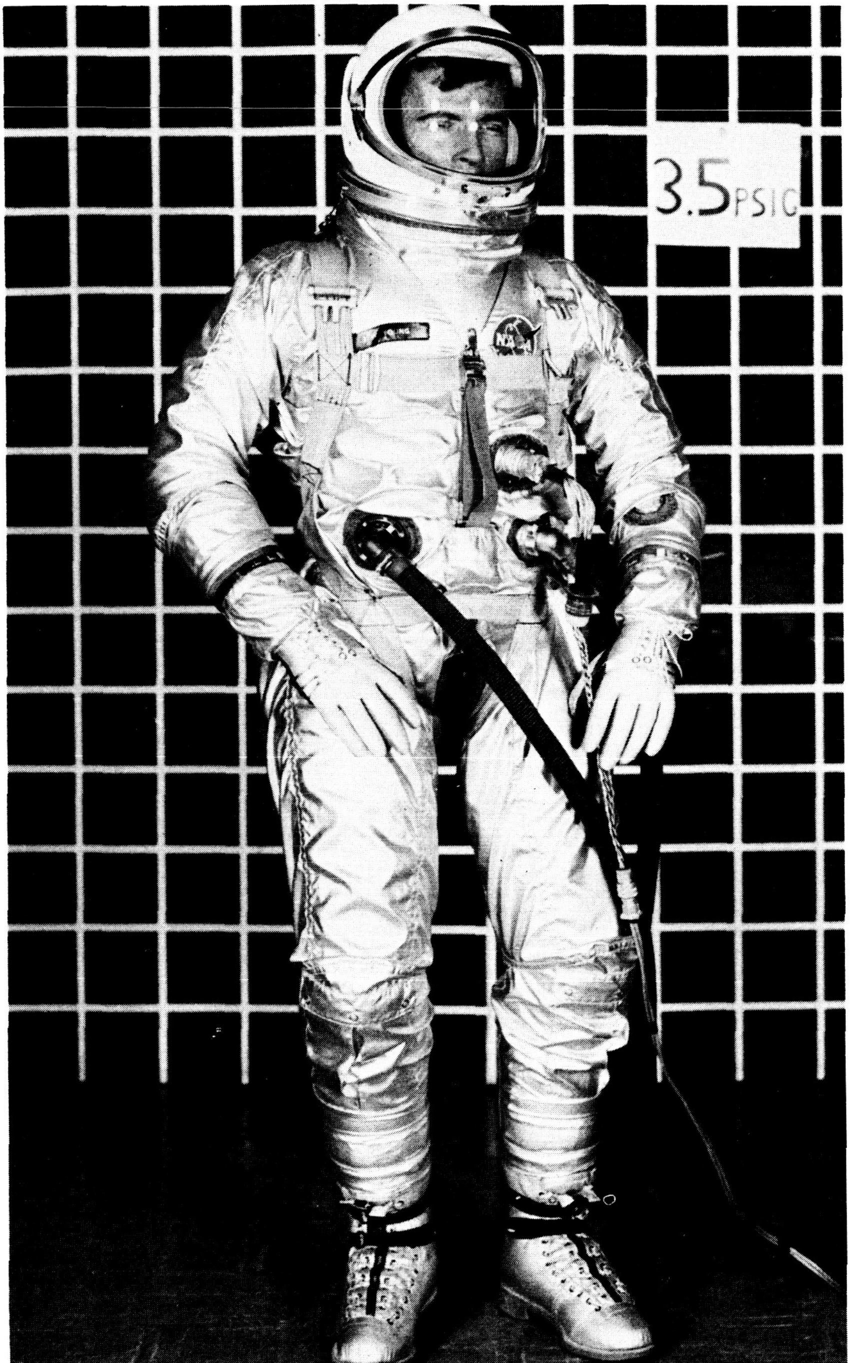


Figure 1–6. Gemini prototype full pressure suit.

grams were reviewed by small groups of scientists engaged in the day-to-day technical management of individual tasks.

Coordination of the fiscal year 1964 NASA space medicine program with medical elements of the Army and Navy was accomplished through the Department of Defense by submission of detailed NASA space medicine task descriptions. Probably never before in Federal medical research and development has so detailed a comparative evaluation of the research programs of two major agencies of the Government been accomplished.

As a byproduct of the coordination effort, in December 1963 the Associate Administrator for Manned Space Flight directed the establishment of a NASA Space Medicine Liaison Office at the USAF Aerospace Medical Division, Brooks Air Force Base, Tex., under the NASA Director of Space Medicine. This office was to serve primarily as a focal point between Manned Spacecraft Center Life Science personnel and their Aerospace Medical Division counterparts to foster continued day-to-day coordination and to enhance the close working relationships between the two agencies.

Scientific Experiments

The Gemini scientific experiments program was rapidly becoming defined. An extension of the program first undertaken in Project Mercury, it involved experiments generated by NASA, the Department of Defense, and the scientific community.

At the end of the year, a number of experiments for the Gemini program were being considered and some of them were in a semi-approved stage. Meanwhile, the mechanisms were being established in conjunction with the Department of Defense and the scientific community to carry out the experimental program. For this purpose, a Manned Space Flight Experiments Board was established late in the year.

The Apollo Program

Significant and orderly strides continued to be made in the Apollo lunar program—one of the greatest scientific and technical endeavors ever undertaken by any nation. The program evolved rapidly but efficiently at a pace that was consistent with economy —as was revealed by studies that were made. Many of the major facilities, including those for testing, were constructed or were nearing completion. The private contractor base had been established.

The design and development programs proceeded and contractors began the delivery of hardware. As a result, the ground and flight test programs were stimulated. Adoption of the "all-up" testing concept would result not only in more rapid and efficient testing of total systems but also in reduced expenditures.

During this period, also, the test program for the Saturn I/IB launch vehicle was streamlined through the decision to proceed directly to "all-up" tests of the Saturn IB-Apollo vehicle, following completion of the unmanned flight tests of the Saturn I.

In the Apollo program, 1961 and 1962 were years of decision-making; 1963, contracting and beginning of the development and manufacture phase; 1964–65 further development, manufacturing, testing; and 1966, beginning of the flight program.

Schedule Considerations

During the last half of 1963, detailed reviews were made of the factors affecting the time/cost relationship as related to budget planning and of the conditions in the space environment that might affect the schedule.

The time phasing of the Apollo program was compared with other major U. S. research and development programs. The effect on total cost of the overall pace of the program was examined, as well as the possible impact upon the schedule of the effect of the space environment.

It was concluded from the review that the pace of the program was efficient, compatible with economy, and that solutions to the hazards of space flight were available within present technology.

Time Phasing Compared with Other Major R&D Programs—Because design approaches of the Apollo spacecraft and launch vehicles do not differ grossly in principle from previous major developments of a similar nature, it was decided to compare the overall development phasing for the total Apollo program—including the spacecraft, the Saturn IB and Saturn V launch vehicles, and major subsystems—with the development cycles of similar major research and development that had been successful in the past.

The comparison revealed the following:

1. In terms of readiness for mission capability, the Apollo

spacecraft development cycle allowed 1 to 4 years longer than the cycles for the Project Mercury spacecraft, the B–58 bomber, and the X–15 aircraft.

2. The total development time allowed for Saturn V was 1 to 2 years longer than that required for development of the Atlas and Titan.
3. The time allotted for the Apollo guidance system development was 1 to 1½ years longer than that required for the Polaris, Miniuteman, and Titan II systems.
4. Adequate time was allotted for orderly development of the F–1 and J–2 Saturn launch vehicle engines to the high state of reliability desired for the Apollo program in contrast to previous major liquid engines.
5. The overall time allotted for Apollo of approximately 8 years was significantly greater than that for any of the comparable previous programs.

Effect on Cost of Acceleration and Deceleration.—A second time/cost factor studied was the effect on cost of accelerating or decelerating the program—that is, stretching it out over a longer time period or speeding it up.

Some evidence was discovered tending to indicate that a very slight acceleration might result in savings. Certain costs would increase, but some of the fixed operating costs would be reduced.

It was found that deceleration—stretching out the program into the decade of the 1970's—would increase rather than decrease costs. A 3-year deceleration would increase program costs approximately 15 percent; a 6-year stretch-out, 30 percent.

The study revealed that certain fixed operating, personnel, and facilities costs mainly account for the increase. For example, many thousands of skilled engineers, scientists, and technicians are needed to support the flight and ground-test activity that is required throughout the total development program.

These include propulsion, electronics, structures, thermodynamics, astrodynamics, and guidance and control specialists. They also include supporting technicians and clerical and management staffs required by each industrial contractor to remain in business. Certain work must always be done and certain facilities constructed and maintained.

All these costs remain practically the same regardless of program pace, whether launches occur every 3 months or every 9 months as would occur under a stretch-out. Because they accumulate in almost direct proportion to the time required for program completion, a stretch-out would substantially increase them. It would also reduce useful output and require maintenance of a technical-industrial base in low-gear operation over a longer period of time.

Because a considerable portion of the physical plant required for the Apollo program was completed or was being constructed and the industry-Government team largely assembled, one element of the cost of stretching out the program would be the maintenance of idle facilities. Another element identified was the potential waste inherent in the cutback of major contracts.

On the basis of the study, it was concluded that a delay to the mid-1970's, calling for a change of pace, would not only cause a serious loss in stride but it would also cost more money in the long run.

Effect of the Space Environment.—The third major time/cost factor studied in relation to the Apollo schedule was the possible adverse effect of the space environment. The studies in this area were focused on meteoroids, radiation, and the selection of a lunar landing site. It was concluded from the studies that solutions of the environmental problems involved seemed possible using existing technology and knowledge gained during the previous 6 years of intensive space exploration, both manned and unmanned.

Objectives

The major objective of the Apollo program is to achieve U.S. preeminence in space through the creation of the broad range of capabilities required to accomplish manned lunar exploration during this decade. The returns from the investment in Apollo will include the flight hardware required for a broad foundation of operational capability in space and the associated technology; a valuable complex of developmental, test, and operational facilities; a trained Government and industrial team; operational skills; and the ability to manage large-scale research and development. All will open the door to the further exploration and exploitation of space as required by the national interest.

Specific Apollo flight program objectives include unmanned earth orbital qualification flights; manned earth orbital flights, including long-duration and rendezvous-docking missions; unmanned orbital qualification flights; orbital lunar mission simulation; and luner landing and exploration. (See fig. 1–7, the Apollo mission profile.) The launch vehicle for the first two

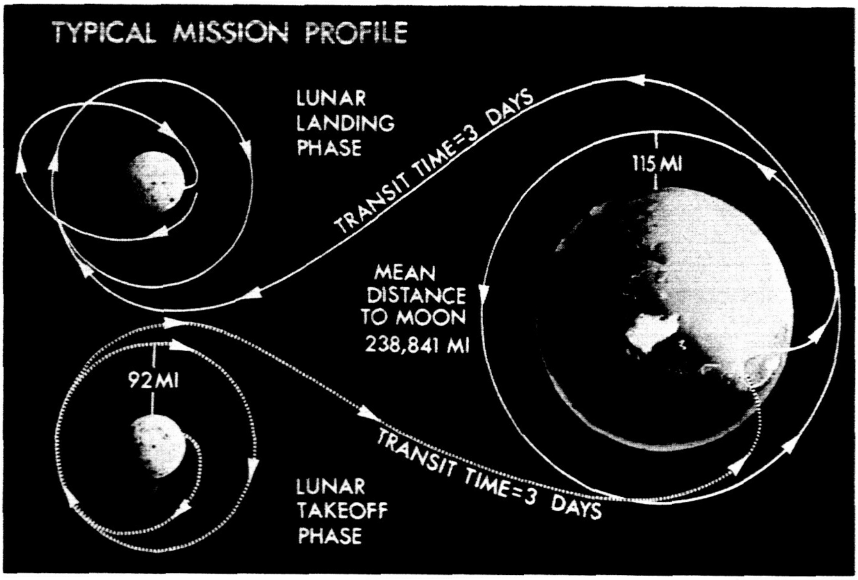


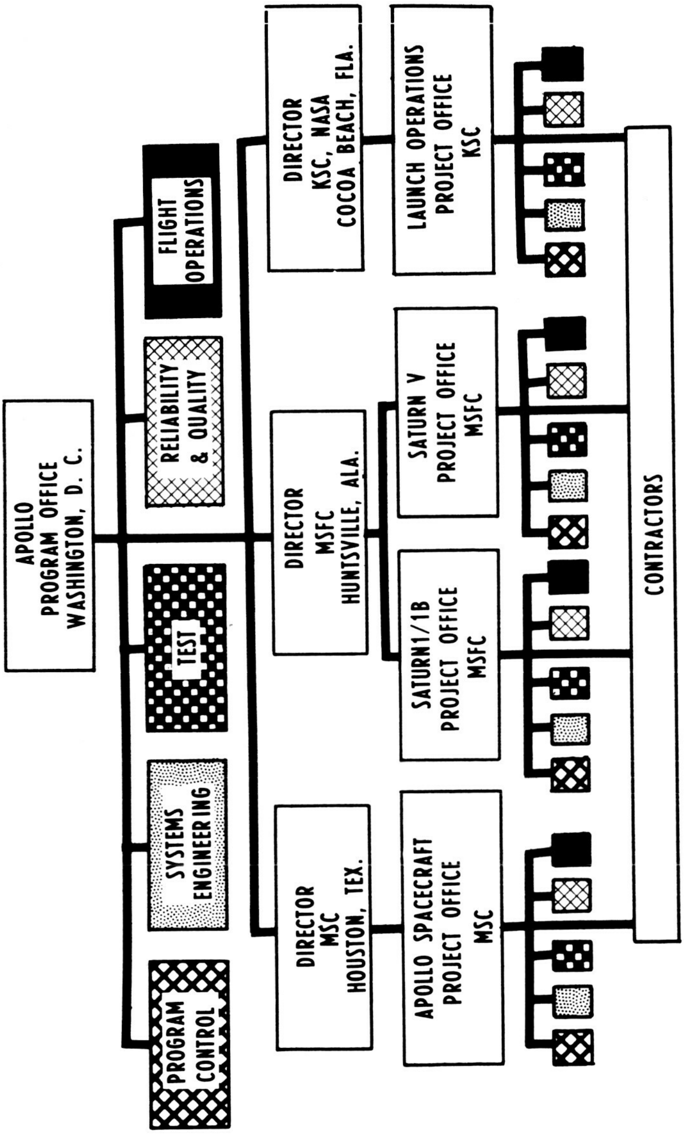
Figure 1–7. Apollo mission profile—the lunar orbital rendezvous mode.

of these is the Saturn IB; the Saturn V will begin to be used with the third.

To accomplish the objective of landing two astronauts and their scientific equipment on the moon and returning them, the two launch vehicles must be developed and qualified for manned flight. A highly reliable spacecraft must be developed that is capable of supporting man in space for periods of 2 weeks, docking in space, landing on the hostile lunar surface, and safely reentering the earth's atmosphere at 36,000 feet per second within a precise reentry corridor. The equipment reliability, thermal protection, and guidance accuracy requirements are many orders of magnitude beyond those of the successful Mercury program.

Management

The Apollo program, because of its vast scope and the wide geographic dispersion of the participants, requires special management arrangements. This program brings together more than 14,000 persons in the 3 Centers, who were held responsible in turn for managing the efforts of 200,000 people in the contract structure by the end of 1963.



NOTE: FUNCTIONAL OFFICES AT CENTERS ARE SHOWN CODED TO CORRESPOND WITH FUNCTIONAL OFFICES IN WASHINGTON PROGRAM OFFICE.

Figure 1–8. Apollo program management.

The Apollo program must also draw together and integrate the supporting resources of the Department of Defense as well as the rest of the NASA organization, including the Goddard Space Flight Center, Langley Research Center, and the Jet Propulsion Laboratory.

The Apollo management structure was strengthened in the last half of 1963 as part of the overall Manned Space Flight reorganization by establishment of the Apollo Program Office and the project offices at the three Field Centers. (See fig. 1–8.)

Apollo Program Office.—The Apollo Program Office was charged with all aspects of program management, including performance, cost, budget, schedule, design, test, and assurance of manned flight safety. It was organized into the following units: Program Control, Systems Engineering, Test, Reliability and Control, and Flight Operations.

In the field four offices were established for the management of major Apollo systems: The Apollo Spacecraft Office at Manned Spacecraft Center; a Launch Operations Office at the John F. Kennedy Space Center; and two offices at Marshall Space Flight Center, one for the Saturn I and IB, and one for the Saturn V. Each of these four offices were to be broken down into five functional elements, corresponding to the five functional units in Washington.

Means were established for a rapid, free flow of information between the Apollo Program Director and each of his functional elements on the one hand and their counterparts in the field on the other. However, directives from the Apollo Program Director flow through line organizational channels. This line of authority includes the Center Directors.

In the new organization, the Center Director's role is one of providing the broad base of technical support for the project offices, which depend upon this support for the actual carrying out of the detailed design and supervision of the contractors' work. The Director is also responsible for making certain that technical program work is being properly accomplished.

NASA-Industry Apollo Executives Group.—Because the industry base accounts for the bulk of total NASA activity in the Apollo program, corporate management has an indispensible role to play in the success of the program. It is essential to establish good communications and rapport between top management of Manned Space Flight and the major Apollo contractors.

The effectiveness with which this activity is directed will depend in large part upon providing to company executives the program perspective they require and in obtaining from them knowledge about their front-line problems. For this reason, the NASA-Industry Apollo Executives Group was established. It held its first meeting on October 24, 1963.

This Group was to meet with the Associate Administrator for Manned Space Flight periodically at various contractor and NASA locations throughout the country for status briefings and consideration of major problems affecting the progress of the Apollo program.

Systems Engineering

Systems Engineering provides program-wide technical analysis and guidance to insure that the functional and performance requirements placed on all elements of the Apollo system are within the present or projected state-of-the-art and can be developed within the scope of the program.

Considerable analytic work was carried out during the period in the study of flight trajectories of all phases of the mission. This was done to determine the interactions of vehicle weights, fuel consumption, guidance, and navigation characteristics, and to allow for the establishment of alternate or emergency mission profiles. Included in this work was an investigation of the effects of selecting a particular lunar landing site and of particular lunar lighting conditions on hardware requirements.

Special investigations were also carried out in such areas as guidance and navigation, propulsion systems, fuel cells for the production of electric power, and environmental control systems.

Development and Testing

During the period, NASA continued to move forward with the development and testing of Apollo spacecraft, launch vehicles, and related engines. (See fig. 1–9.) Also the "all up" flight testing concept was adopted.

Spacecraft.—The Apollo spacecraft, being developed by an industry-Government team under the leadership of the Manned Spacecraft Center, consists of three sections, or modules: The command module, the service module, and the lunar excursion module.

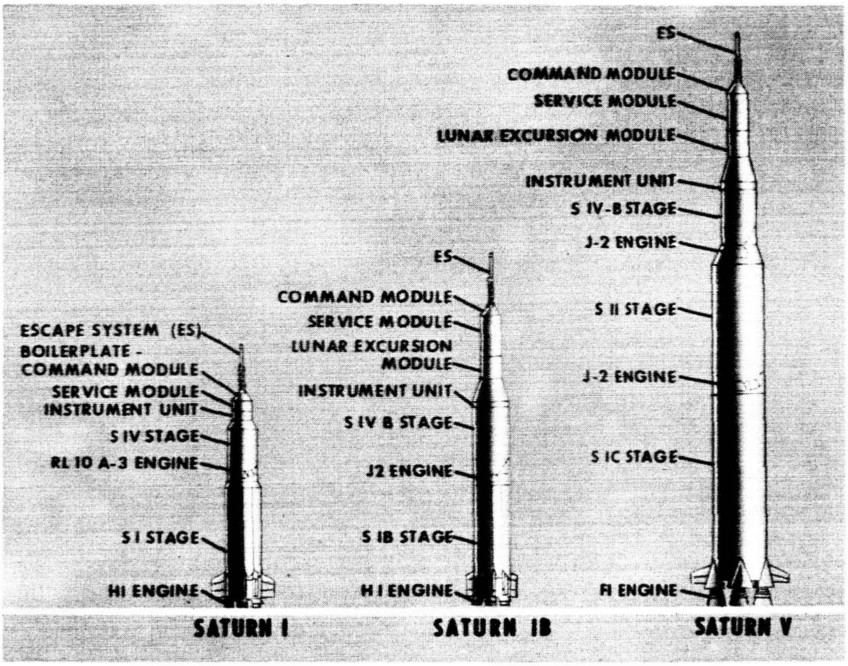


Figure 1–9. Apollo space vehicles.

The command module, one of the most complex manned flight devices ever designed, will be manned by three crew members. It will contain many systems required to perform the mission: The environmental control system, which will provide the proper atmosphere; a communication system, for contact with the control center on earth; a guidance and control system, together with its associated computing devices and pilot displays, to allow for the proper execution of the mission; and a landing system, to provide for a touchdown at a fixed location on earth.

The service module will be equipped with rocket engines and fuel supplies to enable the astronauts to project their craft into and out of lunar orbit and to change their course in space. It also has a reaction attitude control system to stabilize the spacecraft in the proper attitude for various mission phases. Its 21,900-pound-thrust engine provides a multiple restart capability in space. The service module will also contain the fuel cell and reactants which will supply the spacecraft electrical power supply.

The lunar excursion module (LEM), shown in fig. 1–10, consists of a command center upper stage (ascent) and a lower landing stage (descent). The upper stage houses the two-man crew and is the control center during all phases of the lunar landing, stay, and return to lunar orbit. All crew-initiated control functions will be performed in this stage. (During the launch and earth orbit, the LEM will be housed within an adapter located between the service module and the Saturn IB or V launch vehicles.)

The upper stage contains all systems necessary for crew support, guidance, navigation, control, electrical power supply lunar descent, exploration, and return to the command and service modules in lunar orbit. It also is equipped with the LEM reaction control system for both stages and the propulsion system for launch from the lunar surface and return to the orbiting command and service modules.

The lower landing stage contains the landing gear; the landing aids, components, and systems not required for the return to lunar orbit and rendezvous; and the landing propulsion sys-

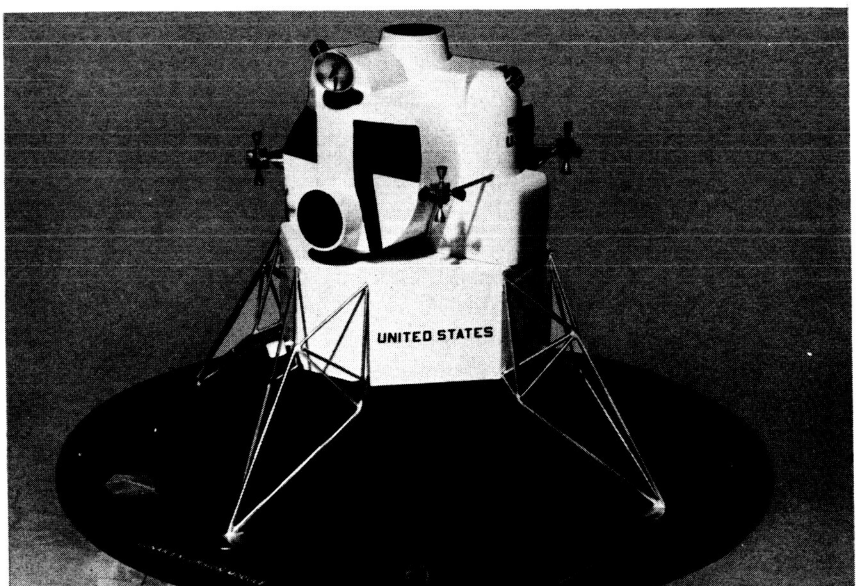


Figure 1–10. Lunar Excursion Module (LEM).

tem. This propulsion system will provide all LEM propulsion needs for separation from the command module, descent for terminal landing, hover, translation, and landing on the lunar surface.

Among the major subsystems of the Apollo spacecraft are the various propulsion systems. On these, a rigid development effort is being followed to assure maximum reliability. The service module propulsion engine was undergoing tests at Sacramento and at the Arnold Engineering Development Center, Tullahoma, Tenn. Plans were made for testing it in conjunction with the complete service module propulsion system at White Sands Missile Range. The engine is rated at 21,900 pounds thrust and uses earth-storable, hypergolic (self-igniting) propellants.

The LEM descent engine is similar in design concept to the service module engine except that its thrust is controllable, from 1,050 pounds to a maximum thrust of 10,500 pounds. This throttling capability, so necessary for the actual lunar landing operation, increases greatly the complexity of the engine development.

To insure the attainment of this capability, two different engine contractors continued parallel development efforts. At a point when the major development problems are overcome, the more promising of the two engines is to be selected.

The Apollo spacecraft ground tests were initiated in early 1962. At the end of 1963, boilerplate command and service module and ground test program and subsystems tests were well along.

The boilerplate tests were scheduled to start as soon as the physical parameters—shape, weight, center of gravity location and the like—are established and the boilerplate modules can be fabricated. The objectives are to verify the physical parameters and to develop other components and subsystems.

The ground test program of boilerplate command and service modules was continued during this reporting period; the shipboard rig tests and rough-water tests were completed. Flotation and handling tests in Galveston Bay were approximately 60 percent completed. The impact test program, in which the impact attentuation system and crew shock absorption system are evaluated, was approximately 50 percent completed.

Parachute drop tests of command module boilerplates were approximately 30 percent completed, nine parachute drop tests of an Apollo command module boilerplate having been made.

Design and engineering on all major subsystems to be used in the command and service modules were completed during the last half of 1963, and development testing was begun. Development continued on the service module fuel cell, which will supply on-board power during the astronauts flight to and from the moon. The subcontractor delivered the first service module fuel cell modules to the prime contractor for systems tests.

Development of the launch escape system, essential for astronaut crew safety during countdown and shortly after liftoff, was completed on a boilerplate system, and this system was essentially ready for qualification testing. (See fig. 1–11). The Little Joe II launch vehicle, a relatively simple solid propellant rocket, was being used to obtain early test flights on the launch escape system.

The first flight in August 1963, at White Sands Missile Range, successfully verified the launch vehicle performance and launch operations associated with the flights. In November 1963, a pad abort test of an Apollo boilerplate command module was conducted with satisfactory results.

LEM ground testing was scheduled to begin in late 1964. This was to parallel the command and service module ground tests. Special emphasis was to be placed on simulated operations in a lunar environment. Fabrication was started on the first two of nine LEM test articles for ground development tests to be delivered by the contractor. Twelve LEM flight test vehicles for developmental and operational flights are also to be delivered. Mockups for ascent engine, descent engine, and environmental control system were delivered to the contractor for use in design and development effort.

Single cell developmental testing for the LEM fuel cell was initiated by the contractor. Preliminary landing gear stability drop tests were completed. Cabin and crew station layouts were approved for detailed design implementation. Propellant tank and structural arrangements were determined. The rendezvous-docking hatch design was selected. A more definitive mission and trajectory analysis resulted in significant revisions to the required velocity increments.

The guidance and navigation system for the spacecraft will allow the astronauts to navigate from the earth to the moon during the lunar landing, during the LEM rendezvous with the command module (in lunar orbit), and during the return of the command module to a landing on earth.

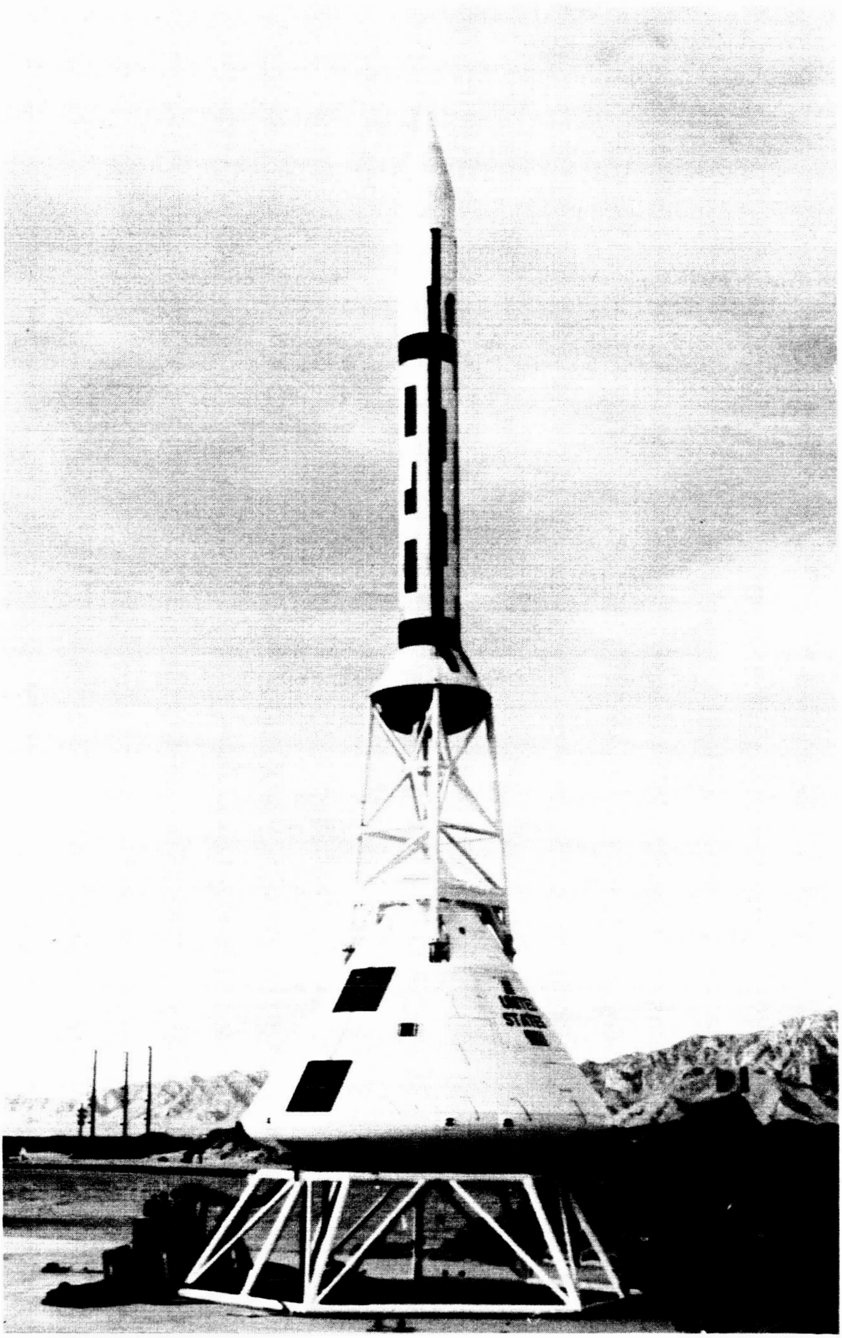


Figure 1–11. Launch escape system and command module.

The Massachusetts Institute of Technology and a team of industrial support contractors have the responsibility for providing guidance and navigation equipment for the command module and lunar excursion module. The Institute is responsible for developing the system, fabricating initial prototypes, and providing NASA with technical assistance in directing the industrial contractors in the fabrication of the system.

Extensive environmental and mechanical tests were completed on prototype units at the Institute to verify design, and the reliability test program was well underway at the end of the year. Preliminary design of the LEM guidance and navigation system was completed during the period.

Launch Vehicles.—Launch vehicle development involves the coordination of the efforts of many aerospace industry contractors. This is done by the Marshall Space Flight Center. The contractors and subcontractors are responsible for producing hardware that meets the specifications established by the Manned Spacecraft Center and the Marshall Space Flight Center. The launch vehicles being developed are the Saturn I, Saturn IB, and Saturn V.

Saturn I is being developed in two configurations: Block I and Block II. Block I consists of a live first stage (S–I), which has a cluster of eight H–1 oxygen/kerosene engines, each providing 165,000 pounds of thrust; a dummy second stage (S–IV); and a dummy payload. Block II consists of an improved version of the same first stage (the H–1 engines were uprated to 188,000 pounds of thrust each) and a live second stage utilizing a cluster of six oxygen/hydrogen RL–10 A–3 engines (each engine providing 15,000 pounds of thrust.)

Prior to this reporting period, four Saturn I Block I tests had been successfully conducted. Starting with the fifth Saturn test (SA–5), NASA planned to use live second stages. The SA–5 vehicle was delivered to the John F. Kennedy Space Center and was scheduled for flight in the first quarter of 1964. (The SA–5 was successfully launched January 29, 1964.)

During this reporting period, the first contractor-produced S–I stage at the Michoud Plant was completed and accepted by NASA. The production of this stage was a major milestone in the transfer of S–I stage assembly from the Marshall Space Flight Center to the Michoud Plant. The seventh S–I stage (S–I–7) was static tested in November. (See fig. 1–12.) Two additional stages were being assembled; these include the second stage to be assembled at Michoud (S–I–10) and the last as-

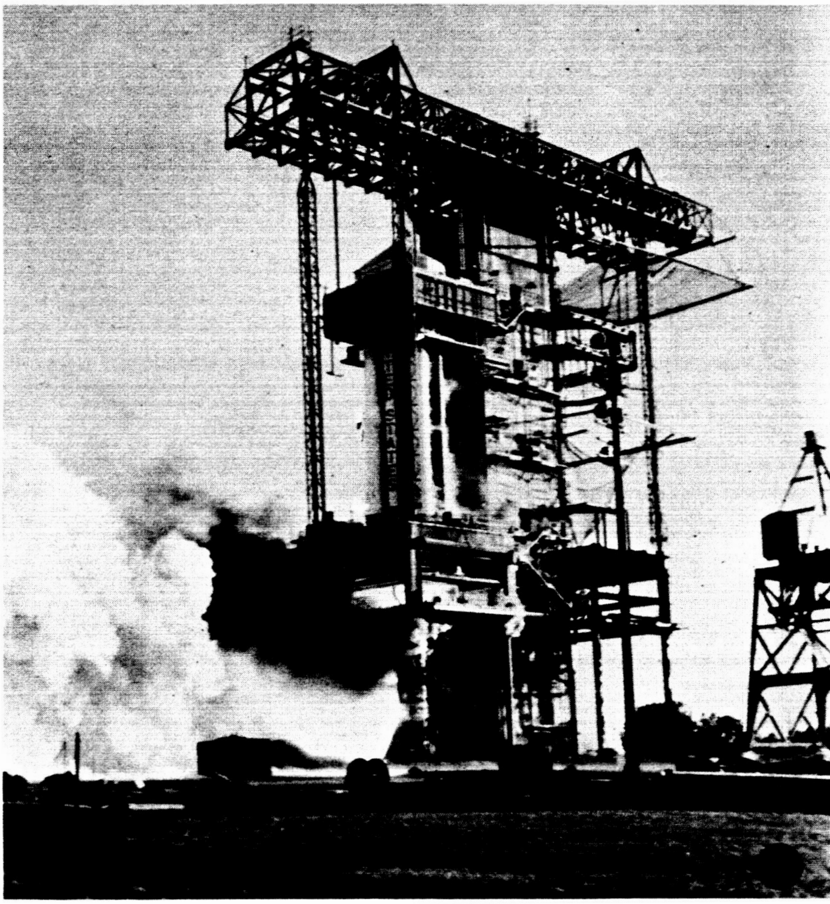


Figure 1–12. S-I stage static firing at Marshall Space Flight Center.

sembly at the Marshall Space Flight Center (S–I–9). These will complete deliveries of S–I stages.

Qualification testing of the S–IV stage was completed. The first hot firing of a flight weight stage (S–IV–5) was conducted at Sacramento, Calif., in August; the stage was accepted and shipped to the John F. Kennedy Space Center for assembly into the SA–5 vehicle in September. Hot static firings of the next S–IV–6 stage were completed in November. Assembly of the last four S–IV stages (7, 8, 9, and 10) continued on schedule.

The preliminary qualification test of an experimental RL–10 A–3 engine, used in the Centaur upper stage of the Atlas-

Centaur as well as in the S–IV, was successfully completed. The engine was successfully flight tested in the Atlas-Centaur vehicle on November 27, using a cluster of two engines.

Flight readiness firings of the S–IV stage, employing six RL–10 engines, were successfully accomplished for S–IV–5 and S–IV–6. Delivery of RL–10 engines for the remaining Saturn I flights was completed. Development of the engine continued, emphasis being placed on increased impulse for greater payload capability and low-thrust capability for applications which require extended coast periods.

The Saturn IB is also a two-stage vehicle and has an instrument unit. The first stage, S–IB, is powered by eight H–1 engines, each uprated from 188,000 to 200,000 pounds of thrust. This gives the S–IB stage a total thrust of 1.6 million pounds as against 1.5 for the S–I stage of the Saturn I. The S–IVB second stage consists of a single 200,000-pound-thrust oxygen/hydrogen J–2 engine in place of the six RL–10 A–3 engines used in the S–IV stage of the Saturn I.

During the last half of 1963, design and development of the S–IB stage continued. Various component designs were completed and released for fabrication. These included the second stage adapter, seal plate, tail section assembly, and heat shield.

Several major improvements were incorporated into the H–I engine, used in the first stage of Saturn I and IB. A stainless steel thrust chamber, a turbopump having improved bearings, gears and inducer, and a dynamically stable injector were released to production for the qualification configuration engine. The engine has been tested at 200,000 pounds thrust for use on the Saturn IB and is capable of extensive operation at this thrust level with some additional minor improvements of the chamber and turbopump.

Major tooling fabrication of the S–IVB stage continued. Fabrication of structure for all systems and battleships testing continued on schedule. The first J–2 engine was delivered to the stage manufacturer for cold-flow tests. Substantial progress was made by the subcontractor on the 150-pound thrust attitude control rockets.

Considerable progress was also made toward developing the Block III J–2 engine, the configuration for the Preliminary Flight Rating Tests (PFRT). Successful completion of this test will provide assurance that this engine is suitable for use in vehicle ground tests.

Two noteworthy milestones were passed in the reporting period. The first was the successful completion of the 500-second duration engine test of the J–2. Heretofore, the engine test facility was limited to 250-second runs. However, activation of two 500-second capability test positions during the period permitted the engine hardware to be tested to the mission requirements. The second milestone was the delivery of the first cold-flow J–2 engine for vehicle ground testing to the contractor in November 1963.

The Saturn V consists of the S–IC stage, the S–II stage, the S–IVB stage, and the instrument unit. The S–IC stage consists of five 1.5 million-pound-thrust F–1 engines, which produce a total thrust of 7.5 million pounds. This stage is being designed at the Marshall Space Flight Center and is to be contractor produced at the Michoud Plant.

The S–II stage, being designed by a contractor, is powered by a cluster of five 200,000-pound-thrust J–2 engines, such as were developed for the S–IVB stage of Saturn IB. The third stage, S–IVB, is essentially identical to the second stage of the Saturn IB vehicle, including the instrument unit, and is powered by one J–2 engine.

During this reporting period, initial design of structural, propulsion, instrumentation, installation, and electrical hardware of the S–IC stage proceeded on schedule, and fabrication of components

Figure 1–13. S-IC upper thrust ring.

and subsystems for the first all-system stage test was initiated by the contractor. (Fig. 1–13 shows the S–IC upper thrust ring.)

During this reporting period, consistently stable F–1 engine operation was achieved. Considerable attention was devoted to the design of the injector, a device similar in concept to a shower nozzle, which mixes the kerosene and oxygen in the combustion chamber. It was found that certain injector-engine combinations tended to create instability spontaneously, while other combinations operated in a completely satisfactory manner.

Although a stable injector was developed, effort was continued to obtain an optimum injector of maximum stability with increased performance. As a result of tests, NASA selected the baffled injector to assure successful completion of the informal preflight rating tests.

Production of engines for use in the S–IC stage continued. (Fig. 1–14 shows F–1 engine test firing.) The first production engine was acceptance tested, shipped to Marshall Space Flight Center, and began undergoing tests.

During the reporting period, initial design of the S–II stage structure was completed, and design of the propulsion, electrical, and instrumentation installation hardware continued on schedule.

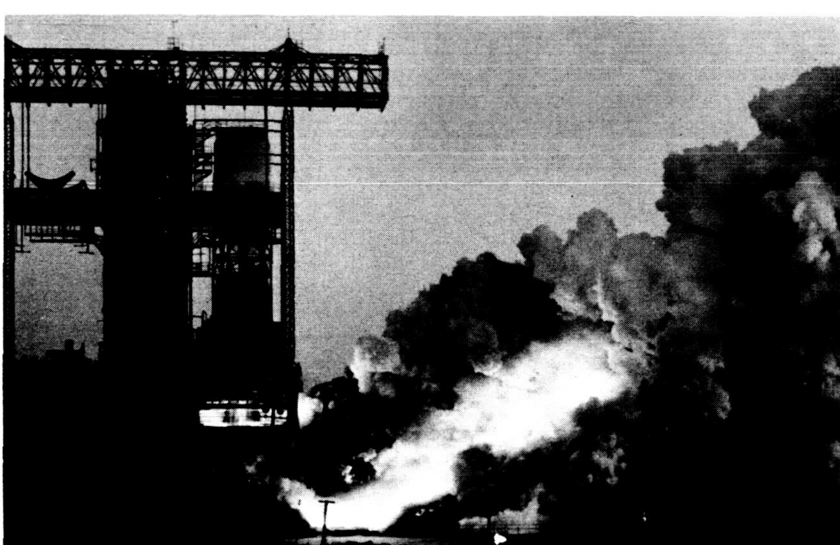


Figure 1–14. Development test firing of F-1 engine.

Fabrication of the structure for the battleship stage was completed on schedule. The stage was installed in the battleship test stand at Santa Susana, Calif. The structure portion of an electromechanical mockup was completed at Downey, Calif., and bulkheads for the flight stages were being fabricated at Seal Beach.

Adoption of "All-up" Testing.—A major decision was made in 1963 involving adoption of the "all up" concept as a basic approach to the Apollo flight verification test program. In "all up" testing, all flights will be scheduled with complete space vehicles, using live stages.

A step-by-step procedure had been used in the past. Recent successful events—such as four S–I stage launches, ground tests of the liquid hydrogen second stage for Saturn I, the launching of the Centaur with its hydrogen upper stage, and the results of the Air Force Minuteman program (which also used "all up" testing)—showed that the technology and experience had reached the point where the step-by-step procedure could be dropped.

The "all up" approach has several advantages, including budgetary. It allowed the cancellation of six previously scheduled Saturn I flights, the complete elimination of all Saturn I manned flights, and the acceleration of the Saturn IB program.

It will permit the fullest exploitation of successful flights. It will also provide a very large amount of data early in the flight program, and thereby provide much-needed information to the design organizations. Finally, by testing essentially complete spacecraft on earlier flights and by acquiring more data per flight, the probability of meeting scheduled dates for the manned lunar landing is improved.

In the Saturn IB and Saturn V programs, under the "all up" concept, NASA plans to launch a complete unmanned space vehicle on the first flight in an earth-orbital trajectory.

Astronaut Training

In addition to their general and Gemini training in the last half of 1963, the astronauts began preliminary training for the Apollo flight test program. They participated in the design and development of spacecraft, full-mission simulators, and life support systems.

Apollo Systems Trainers, similar to those used for Gemini, were to be available in Fiscal Year 1964, and they were scheduled to be operational for crew training in early 1965. Training of the astronauts in centrifuge trainers for Apollo mission g-profiles was expected to begin in 1964.

A unique vehicle that was scheduled to become available in the second quarter of 1964 for operational research and ultimately for crew readiness training is the free flight lunar landing research vehicle. It is a single seat, jet-powered, free-flight vehicle that can simulate the lunar excursion module landing profile and the necessary control requirements for a lunar environment. Crew safety provisions include a rocket-powered ejection seat for zero-zero airspeed/altitude capability.

Helicopter training for astronaut personnel was initiated during 1963 preparatory to simulating flight profiles for the lunar landing phase of the Apollo mission. The Navy loaned NASA a helicopter to be used at the Manned Spacecraft Center for this training.

Aerospace Medicine

Major elements in the Apollo space medicine program are the development of the extra vehicular suit and the portable life support system.

In 1963, the Apollo prototype suit design was completed, fabrication of the suit was initiated, and delivery and evaluation of the first prototype mobility suits were accomplished. Thermal balance capacity was still being evaluated. Fabrication of the final prototype, as well as contractor evaluation and delivery to the Manned Spacecraft Center, was to be the next step.

Design of the prototype portable life support systems, initiated in 1962, was completed and fabrication of the prototype begun. One prototype was completed and delivered to the Manned Spacecraft Center. Fabrication of the training portable life support system units was scheduled. This will be followed by fabrication of the flight system.

A contract was awarded for development of a carbon dioxide detector for environmental control. A flight prototype was developed and evaluated, the contract for flight hardware effected, and the development action initiated. Also, a prototype gas chromatograph was evaluated.

Bioinstrumentation efforts included work on an impedance pneumograph, a blood pressure measuring device, a body temperature instrument, and an electrocardiograph instrument. In addition, work started on an extravehicular suit signal conditioner for respiratory measurements and on development of additional biomedical instrumentation.

Studies of lunar reentry "g" forces were planned and initiated; centrifuge tests were run as a part of this effort and data obtained for analysis. A compilation of human capacities and limitations, including reactions to stresses, was prepared during the July–December period for use of Apollo engineers in developing systems specifications.

Scientific Experiments

During the last half of 1963, preliminary planning continued for Apollo missions. Observation of the moon itself was to be the primary scientific activity. The principal initial scientific interest is in the structure of the moon's surface and gross body properties. Large-scale measurements of physical and chemical characteristics were being planned, and lunar surface and other phenomena were to be observed.

The NASA Office of Space Science and Applications determined that initial Apollo activities will be limited to the fields of geology, geophysics, geochemistry, biology, surface physics, and investigation of the lunar atmosphere.

The geological field work, which does not involve instrumentation, is to be augmented by the collection of samples that will be returned to the earth for petrographic and mineralogic study. Samples also are to be obtained for quantitative chemical analysis and biological investigation.

It was planned that geophysical investigations on the moon would make use of advanced instruments, specially designed for operation in the lunar environment, for active and passive seismology; and for magnetic, heat, and gravity measurements. Additional special instruments would be used for studies of the lunar atmosphere.

Long-life instruments would be emplaced and adjusted at key points selected by the astronauts for the continued monitoring of geophysical and surface physics characteristics. This program was being planned in close coordination with the National Academy of Sciences and leading scientists.

Advanced Manned Missions

Because America's future in space will not end with Project Apollo, it is necessary to make orderly plans for the follow-on steps in the evolution of the national manned space program. NASA must carefully delineate the scope of the effort involved and then point out the most desirable course. The Advanced Manned Missions Program provides NASA management with the information necessary to perform this task.

This program develops missions, weighs alternatives, and prepares project proposals. It also conducts technical studies to provide information as to the types of missions to be undertaken, the requirements for new systems, the growth possibilities of systems presently being developed, and the possible extension of scope in current programs. Consideration is given to the impact on national resources of future projects and to the desirability of continued use of the flight hardware and facilities being developed for current programs.

In planning, the Advanced Manned Missions office is in close touch with other groups, both inside and outside Government, that are concerned with the Nation's space activities. These include the President's Scientific Advisory Committee, the Space Council, the National Academy of Science, NASA's Office of Advanced Research and Technology and the Office of Space Science and Applications and, of course, the aerospace industry and the scientific community.

By the time the Apollo lunar landing has been accomplished, the Nation will have developed the scientific and engineering skills and industrial capability to forge ahead into other space endeavors. Having developed the basic Apollo hardware, it will be equipped to support the follow-on programs. Because of the leadtimes involved, some of the possibilities and alternatives must be examined now.

During the last half of 1963, studies in these and other areas continued, including associated launch vehicle requirements. Also, all advanced manned mission studies were consolidated in one program office as part of the November 1 reorganization.

Resources

In the last half of 1963 occurred the continued steady buildup of resources in the areas of facilities, logistics, and Department of Defense support—each of which is required to achieve manned space flight objectives. Significant accomplishments were being made at the Marshall Space Flight Center and its related installations in the development, production, and testing of the large launch vehicles required for the Apollo program.

The resources required by the Manned Spacecraft Center for Gemini and Apollo spacecraft development, production, testing, and operations were progressing rapidly. The development of the launch operational resources at the John F. Kennedy Space Center was on schedule. All the essential program resources required were identified, and their acquisition was either initiated or expected to be in 1964.

Facilities

Facilities resources can be grouped into four principal categories: Institutional, design and manufacturing, development and acceptance testing, and operational.

Institutional.—The largest of the institutional facilities is the Marshall Space Flight Center at Huntsville, Ala. This Center is systematically evolving from its earlier mission of large space vehicle development, manufacturing, and testing to the management and administration of industrial firms producing and testing large boosters and engines.

Several institutional improvements were underway in the July–December 1963 period. For example, the expansion of the Computation Facility was started. Construction of the Components and Subassembly Acceptance Building began, and a new Engineering and Administration Building was nearing completion. The Hydraulic Test Facility and the Low Temperature Test Facility were also nearing completion.

Work continued on a new Engineering Building in the test laboratory area. Also underway was an Instrument Laboratory which will support test operations. Support facilities were being expanded to increase the capacity of the high-pressure water, fuel, liquid oxygen, helium, and liquid nitrogen systems to accomodate static testing of the Saturn V vehicle.

At the Manned Spacecraft Center, Clear Lake, Tex., located about 20 miles southeast of downtown Houston, the institutional resources had progressed from an undeveloped area in early 1962 to a center nearing completion by the end of 1963.

These resources support the NASA management of the spacecraft programs, the management of the spacecraft contractors, and the NASA inhouse development and test and evaluation effort for the spacecraft at the Center and at the White Sands Missile Range. All the resources are required in support of the Apollo program, although they are suitable for use with Gemini and any future programs.

In late 1963 the first contingent of personnel began occupying the Central Data Facility, Heating and Cooling Plant, Fire Station, Water Plant, Sewage Plant, support shops, and offices. The utility system was completed, and site development was practically complete.

Major construction contracts were awarded for the Environmental Testing Laboratory (housing two vacuum vessels, one of which will be capable of accommodating the entire Apollo spacecraft), The Thermochemical Test Facility, the Flight Acceleration Facility (which will house a 60-foot centrifuge), and the Integrated Mission Control Center, which has the capability to control Apollo and Gemini missions.

All NASA launches of manned spacecraft will be made from the John F. Kennedy Space Center, the main portion of which will be located on Merritt Island. The purchase of the 87,400 acres on Merritt Island was in the final stages of acquisition at the end of 1963.

Excellent progress was made during the last half of the year in constructing Launch Complex 39, Manned Spacecraft Center facilities, support facilities, and extensive road and utilities systems.

Design and Manufacturing.—The second aspect of the facilities resources pertains to design and manufacturing capacity. The manufacture of large launch vehicles is carried out by the individual stage contractors at Government-owned plants or at the contractor's plant. Contractor resources are supplemented by the Government when special tooling peculiar to the specific stage is required. Such equipment is returned to the Government at the termination of the contract.

The prime contractor for the design, development, and manufacture of the Gemini spacecraft has constructed several new facilities and has modified or added to existing structures. All facilities have been contractor funded.

The Michoud Plant is a Government-owned facility in which contractors are producing the S–I and S–IB stages for the Saturn I and Saturn IB programs, and the S–IC stage for the Saturn V program. For the S–I and S–IB stages, all major modifications to the manufacturing building were completed.

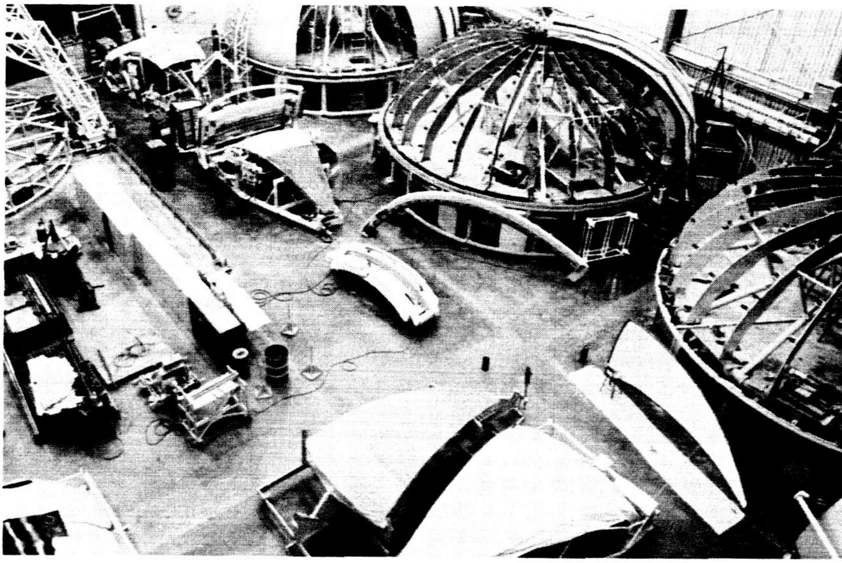


Figure 1–15. S-II bulkhead fabrication.

Construction of the high bay Vertical Assembly and Hydrostatic Test buildings, initiated in October 1962, continued. The new Engineering Building had been started in the spring of 1963. Modifications to the plant for activation of the S–IC area were progressing on schedule.

Seal Beach, Calif., is another Government-owned facility that is being constructed for contractor use in the production of the S–II stage of Saturn V. Construction began at this site late in 1962. By the end of 1963, the Bulkhead Fabrication Shop, the water conditioning facility, and the service building were completed. (See fig. 1–15.) Construction of the Vertical Assembly and Hydrostatic Facility, initiated in April 1963, was progressing on schedule.

Huntington Beach, Calif., a constractor-owned site, is a newly constructed facility in which the S–IVB stage will be produced. Installation of some returnable special Government test equipment and testing towers, provided to supplement and complete the production program, was on schedule during the last half of 1963. The S–IVB portion of the plant became operational late in the year.

Modifications and additions were made to the manufacturing and production facilities of Air Force Plant 16 at Downey, Calif. Six major new construction contracts for production resources were awarded in 1963. In addition to the spacecraft production in the Downey plant, some S–II component production was also in progress.

At Bethpage, Long Island, the contractor responsible for the design, development, and fabrication of the lunar excursion module has converted many resources at the plant to the Apollo program, and a number of new resources were being provided by the contractor. By the end of 1963, the new Engineering Center Building 25 was completed and in use. A new office building was in the final stages of construction, and a new extension to Building 14 had been completed.

Development and Acceptance Testing.—A third aspect of facilities resources pertains to hardware testing capabilities, both in the developmental phases of the program and in acceptance testing of production equipment.

Marshall Space Flight Center is responsible for much of the developmental testing of vehicle stages, engines, and components in support of the Saturn I, Saturn IB, and Saturn V programs. Resources exist at the Center for testing the Saturn I and IB with related hardware and components, and for testing the H–1 engine.

The S–IC stage static test stand, construction of which was initiated in June 1961, progressed rapidly. The concrete superstructure was completed, and the steel superstructure was in place. The interim conversion of one S–I stage test position for testing the F–1 engine was completed and testing started.

Construction, begun in February 1963, continued on the F–1 engine test stand and the components test facility. Also, construction was started on the advanced Saturn Ground Support Equipment Test Facility. The Hydrostatic Test Facility for the S–IC stage, construction of which was begun in October 1962, was completed in August 1963.

At the Manned Spacecraft Center, one of the primary developmental resources is the Environmental Testing Laboratory. This laboratory will contain two of the world's largest man-rated environmental chambers. They will be used for testing the assembled spacecraft, modules, and systems, and also will be used for conducting astronaut simulated space and lunar operations. The construction of this laboratory was well underway in the last half of 1963.

Another major developmental resource is the Thermochemical Test Facility, in which development test and evaluation of the reaction control systems and the fuel cells for the spacecraft will take place. The contract for this facility was awarded in August 1963 and construction proceeded on schedule during the remainder of the year.

Steps were taken to provide the Manned Spacecraft Center with an Atmospheric Reentry Evaluation Facility, a Launch Environment Facility, and a Spacecraft Control Technology Laboratory. Also to be added were the Environmental Testing Laboratory and a Lunar Mission and Space Exploration Facility.

Santa Susana is the site of the H–1, J–2, and F–1 engine components development programs supporting the Saturn IB and Saturn V programs. Developmental and production resources at this site were supplemented during 1963, and further supplementation was planned in the Fiscal Year 1964 program.

The two-position Delta 2 test stand was completed and used for acceptance testing of J–2 engines in November 1963. Work continued on the superstructures of S–II test stands Coca I and Coca IV.

Edwards Air Force Base, Calif., is one of the sites used for F–1 engine development and acceptance test effort. Construction of the three new acceptance test stands was 75 percent complete in December 1963.

The Apollo facility, located at the White Sands Missile Range, is managed and operated by the Manned Spacecraft Center, Houston, through a resident manager. Elements of both developmental and acceptance testing are conducted there.

Abort tests to qualify the Apollo command module launch escape system require a small launch pad, using the Little Joe II vehicle. The launch pad and service tower to support the first Little Joe II launch were completed. (The initial Apollo pad abort test was successfully accomplished on November 7, 1963.)

Also at White Sands, major contracts were awarded for the construction of the Apollo Spacecraft Propulsion Systems Development Facility for the command and service modules. This facility will include two test stands, a Control Center, a facility for propellant and oxidizer storage and distribution, a preparation building, and an administrative area. It was well along toward completion at the end of 1963. Test Stand No. 1 and the Control Center were complete and instrumentation was being installed.

The Lunar Excursion Module (LEM) Propulsion Systems Development Facility was let out for bid in the latter part of 1963. This facility will provide resources for developing the

LEM propulsion systems and will include three test stands having altitude capability.

During 1963, construction was continued on the two-stand complex for the S–IVB program at Sacramento. The first stand, scheduled for completion early in 1964, is to be used for the "battleship" test program; afterward, this stand will be used for acceptance testing. The second test stand will be used for all-systems testing.

Mississippi Test Facility (MTF), a site solely devoted to acceptance testing, is located on the East Pearl River in southwestern Mississippi, approximately 40 miles from New Orleans. The main test site, comprised of 13,500 acres, is surrounded by a 128,500-acre buffer zone which will be uninhabited but used for farming and lumbering operations. MTF will be responsible for the acceptance testing of the first stage (S–IC) and second stage (S–II) of the Saturn V vehicle.

The Saturn V Test Area will include two single-position S–II test stands and a dual position S–IC test stand. Stages will be transported by barge to and from the stands for testing. Supporting resources for MTF are in the industrial and engineering complexes, located in the western sector of the main test area.

Land acquisition in the test site was complete at the end of 1963 and was more than 50 percent complete for the buffer zone, which was, for the most part, being acquired in easement. Final design for facilities was approximately 80 percent completed. During 1963, the contract was awarded for the first phase of the technical systems which will be required for the testing operations.

Thirty procurement and construction contracts were awarded by the end of the year, when $70 million of construction was in force, including construction of the first test stand for the S–II stage of the Saturn V vehicle.

Construction had begun on the Advanced Saturn Complex, the canal system, the lock, the Laboratory and Engineering Building, the warehouse, the Site Maintenance Building, the Emergency Services Building, electrical distribution systems, and other supporting facilities.

The Apollo Mission Test Resources, where Apollo spacecraft undergo final testing prior to launch, are located in the Merritt Island area at the John F. Kennedy Space Center. Because this was an undeveloped area consisting of timberland and groves, all construction is new.

This construction is to include a radar boresight range, a Parachute and Paraglider Building, an Operation and Checkout Building, a Weights and Balance Building, a fluid test complex, and a Static Test Facility. Construction of the Operations and Checkout Building began in February 1963 and was approximately 70 percent completed by the end of the year.

Operational.—The fourth and final element of facilities involves operational resources. A substantial amount of progress was made on these resources at the John F. Kennedy Space Center.

An extensive program was completed for modifying an existing Titan launch pad, Launch Complex 19, for all Gemini spacecraft. Modifications were under way on the old Mercury launch pad, Launch Complex 14, to accomodate the Atlas-Agena Gemini target vehicle. The Air Force was funding this project, construction of which had started in September of 1962, and the work was progressing on schedule.

After the Saturn I vehicle SA–4 was successfully launched from Launch Complex 34, this complex was modified to provide it with a liquid hydrogen system. The complex will continue to be developed so that it will have Saturn IB launching capabilities.

The capability to launch Saturn I Block II vehicles at Launch Complex 37B was achieved after a long construction and test program. It was operationally ready at the end of the year. This launch complex will also be used to support the Saturn IB program.

Saturn V launches will all take place from Launch Complex 39 on Merritt Island. During this period, the Vertical Assembly Building (VAB) was being built; the Launch Umbilical Towers (LUT's) were being erected; a propellant system for the first pad was under contract; a second pad was being started; and most of the cabling, communications, and similar facilities which link the elements of the complex were under contract.

Ultimately Launch Complex 39 would be provided with a two-pad complex, a completed Vertical Assembly Building, four outfitted LUT's, an Arming Tower, two crawlers, the crawlerways linking the VAB with the pads, and supporting equipment and structures.

Gigantic strides were also being made during the last half of 1963 in the conversion of the Merritt Island area into the industrial hub which will support the Saturn and Apollo programs. Most of the construction under way during the reporting period was expected to be completed in 1964, when the Merritt Island facility was to become partly operational.

A most important ground resource is the Manned Space Flight Network. The network, together with the Integrated Mission Control Center (IMCC) at Houston and the Launch Control Center at Cape Kennedy, constitute the Ground Operational Support System (GOSS). This system provides for gathering data from or about the spacecraft, for transmitting data and instructions to the spacecraft, and for exercising overall command of missions. Work on the IMCC building neared completion at the end of 1963, and excellent progress was being made in the procurement and fabrication of display systems and other equipment.

Logistics

The NASA logistics support problem is similar to that in a Department of Defense research and development program in that only a relatively small number of end items need to be supported. However, operational flights require complete support from manufacture through launch.

For this purpose, the major contractors have established strong logistics offices to support the Apollo and Gemini programs. This support includes spares, personnel training, documentation, field engineering, and transportation. An Apollo Documentation Panel was formed in 1963 to establish and assure uniform requirements for engineering, management, and program documentation.

Transportation.—Through a contract, NASA completed a comprehensive transportation study in 1963. On the basis of this study, the transportation system in support of the manned lunar landing program was completely defined. A detailed Master Transportation Plan was being prepared.

A Boeing B–377 (Stratocruiser) was converted to transport S–IV stages, Apollo spacecraft, F–1 engines, and other outsized equipment. The aircraft was certified by the Federal Aviation Agency and began operation under NASA contract in July 1963. The "Pregnant Guppy," as this aircraft is commonly referred to, transported an S–IV stage from Calif. to John F. Kennedy Space Center in July 1963, reducing the total transit time from test site to launch site to one day, in contrast to 26 days by boat. The "Pregnant Guppy" is shown in fig. 1–16.

An agreement was signed during the July-December 1963 period between NASA and the Military Sea Transportation Service (MSTS) which provided for ship transportation of Saturn stages.

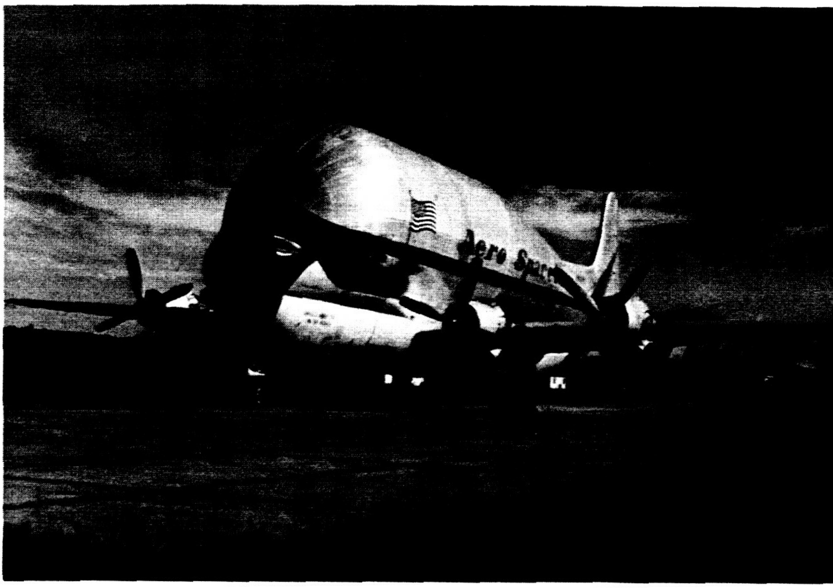


Figure 1–16. The "Pregnant Guppy."

This agreement was the result of exhaustive studies of NASA marine requirements. MSTS was to modify the USNS POINT BARROW (AKD–1) for this service.

The final design of all land transporters for Saturn stages and spacecraft was completed. Transportation design for the lunar excursion module is to be completed when the final LEM configuration is determined.

Cryogenic Supply.—Cryogenic propellant resources on the West Coast were expanded in the last half of 1963. Earlier, a commercially owned 32-ton-per-day liquid hydrogen plant went into operation at Long Beach, Calif. The largest and latest increment of West Coast hydrogen capacity, a 60-ton-per-day commercially owned facility, was scheduled to become operational at Sacramento, Calif., in 1964.

Additional commercial liquid oxygen capacity was made available to NASA in August 1963, and two firms were planning to construct still further additions in Los Angeles and Boron, Calif. Available on the West Coast at the end of 1963 were 6.6 million pounds per month of liquid hydrogen and approximately 40,000 tons per month of liquid oxygen. The available liquid hydrogen capacity and the projected liquid oxygen capacity will be adequate to support West Coast test programs.

An award for a 30-ton-per-day liquid hydrogen supply was to be made which would result in a commercially owned and operated plant in the New Orleans area, located on the inland waterway. The proposed plant would supply liquid hydrogen for testing at the Mississippi Test Facility (MTF), the Marshall Space Flight Center, and possibly other east coast users.

A unique feature of the plant will be the extremely large storage capacity and the capability for barge loading. These will permit accumulation of large quantities of propellant and shipment by barge load lots to MTF via the waterways, resulting in considerable savings in propellant transfer losses and transportation costs.

Special types of barges not only are required for transporting liquid having such low temperatures (—423° F. for hydrogen and —297° F. for oxygen) and high volatility, but will also serve as storage tanks at MTO to directly support the test firings at that location.

Department of Defense Support

The final resource which NASA and Manned Space Flight call upon in carrying out their objectives is that of the Department of Defense (DOD). NASA's first accomplishments were undergirded by its support, and plans called for extensive future use of DOD resources.

For example, the NASA space medicine program has made extensive use of the aeromedical research facilities of the Department of Defense since the start of astronaut selection and training. Most of the astronauts themselves were assigned to the Department of Defense before coming to NASA.

Other examples illustrate DOD support of NASA programs. The Atlas, Agena, and Titan II vehicles are all DOD developments, modified to carry out the NASA Mercury and Gemini programs. The range at Cape Kennedy, used extensively by NASA, is essentially a DOD resource. Extensive use is made of DOD plant representatives at many of the contractors' facilities for quality control, contract auditing, and the like.

Many tests of mutual interest to NASA and DOD are conducted by the DOD in such fields as hazard determination with respect to new propellants being developed. NASA also utilizes DOD procurement channels to effect monetary savings for commonly utilized propellants, as well as the purchase of some directly from DOD facilities, such as liquid hydrogen. Finally, the DOD carries out extensive recovery operations for the manned programs.

Scientific Investigations in Space

During the last 6 months of 1963 NASA prepared geophysical observatories for flight, as it continued to study data on the earth environment, the planets, and interplanetary space transmitted by earlier spacecraft.

Efforts were intensified to determine the hazards of manned space exploration. The 18th in the Explorer series, orbited in the fall, was planned for this purpose.

The Agency considered the possibility of using small satellites completely designed and built by university laboratories, and also decided to launch four satellites built by Canada in a cooperative project of International Satellites for Ionospheric Studies (ISIS).

In August a first step was taken in the joint U.S.-Italian San Marco project when a Shotput sounding rocket was launched from Wallops Island successfully testing the atmospheric drag mechanism—heart of the Italian spacecraft. (Principal objective of the project is to determine the local density of the upper atmosphere in the equatorial plane by launching a satellite into equatorial orbit from a towable platform—like a Texas tower—in the Indian Ocean off the east coast of Africa.)

A highlight of NASA's bioscience programs was the announcement that the launching of the first of six recoverable biosatellites (orbiting biological laboratories) was planned for late 1965.

Geophysics and Astronomy

Two artificial satellites were launched during this report period —Explorer XVIII, to investigate radiation and magnetic fields of vital concern to manned flights in outer space and Explorer XIX, a polka-dotted balloon, to study the density of air at an altitude of almost 1,500 miles.

As in the first half of 1963, emphasis continued on analyzing data supplied by earlier spacecraft, and developing a picture of the space environment near the earth while formulating theories based on this information.

First published results of data supplied by Explorer XVII indicate that it will be possible to determine from these data density and neutral atmospheric temperatures at various latitudes and at different times during the day for altitudes of from 170 to 570 miles. The rigid spherical shape of this satellite—launched April 2 to study the physics and chemistry of neutral gases in the earth's atmosphere—also makes it ideal for measuring atmospheric drag.

Measurements made by the Canadian geophysical satellite Alouette, orbited September 28, 1962, point out that particles from radiation trapped in the Van Allen belts may supply an additional source of energy when they are absorbed in the upper atmosphere, helping account for the atmospheric temperature in these areas.

During the solar eclipse of July 20 (see p. 73) scientists from Goddard Space Flight Center on location in Canada discovered a faint comet only 5° from the sun, verifying what was assumed to be possible.

Color photographs of the whitish green night airglow in the atmosphere taken by Astronaut Cooper during the final Project Mercury manned flight of May 15–16, 1963, revealed this airglow to be about 15 miles thick. The height of the glow seemed to vary with latitude and ranged from about 50 to 75 miles above the earth's surface.

Sounding rockets, launched in night searches for X-rays not originating from the sun, observed several sources of these rays which might be coming from a new class of celestial objects.

Geophysical Satellites

Explorer XVIII, orbited on November 26 from Cape Kennedy, was known prior to launch as IMP–A or the Interplanetary Monitoring Platform (fig. 2–1). The spacecraft carries nine experiments that measure energetic radiation in space and the magnetic field that deflects or traps it. Energetic radiation from the sun or trapped in the magnetic field of the earth can substantially alter the weight and power requirements of the launch vehicle, and, in turn, the design of the spacecraft to protect the astronaut against this hazard, as well as condition the planning for a specific mission.

The satellite was placed in a highly eccentric orbit (with a period of about 4 days) that ranges from 119 miles to a height of

122,800 miles—almost half the distance to the moon. Resembling Explorer XII, launched August 15, 1961, and described in the Sixth Semiannual Report, this Explorer is a relatively flat octagonal box 12 inches high and 28 inches from side to side.

The geophysical spacecraft carries two magnetometers to measure magnetism along its orbit and a cosmic ray telescope to obtain

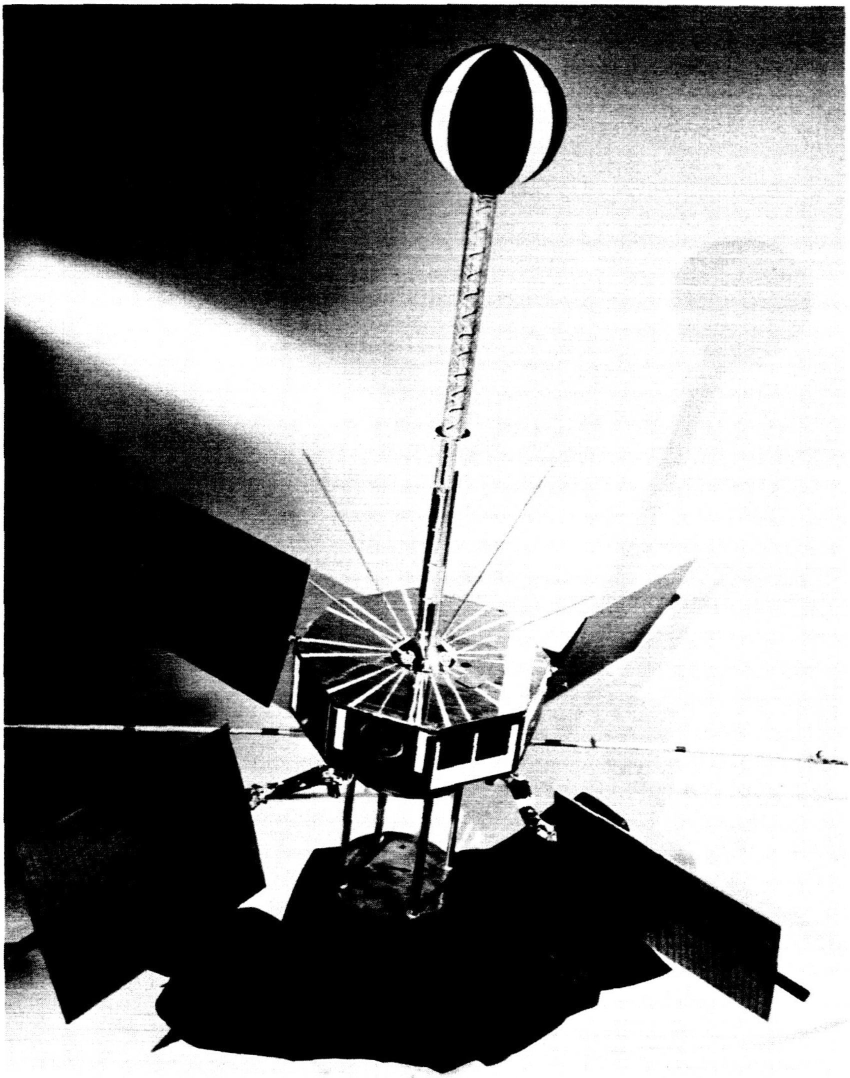


Figure 2–1. Explorer XVIII, the Interplanetary Monitoring Platform (IMP.)

information on solar protons (particles with positive electric charges coming from the sun). Other instruments measure the total energy of cosmic ray particles and their energy loss, record the effects of solar flares on solar protons, and monitor radiation.

All of the satellite's experiments have worked satisfactorily since its launch. However, it is too soon to know the results.

On December 19 the 19th in the Explorer series was launched to extend studies of upper atmosphere density to the polar regions by gaging atmospheric drag on the satellite. Explorer XIX, a 12-foot sphere with white dots painted on its surface for temperature control, is similar to Explorer IX orbited February 16, 1961. (See the Sixth Semiannual Report, pp. 50–51.)

This satellite (fig. 2–2) is made up of alternating layers of thin aluminum foil and Mylar polyester film, and is designed simply to measure atmospheric drag and density. At twilight it can be seen through a low power glass.

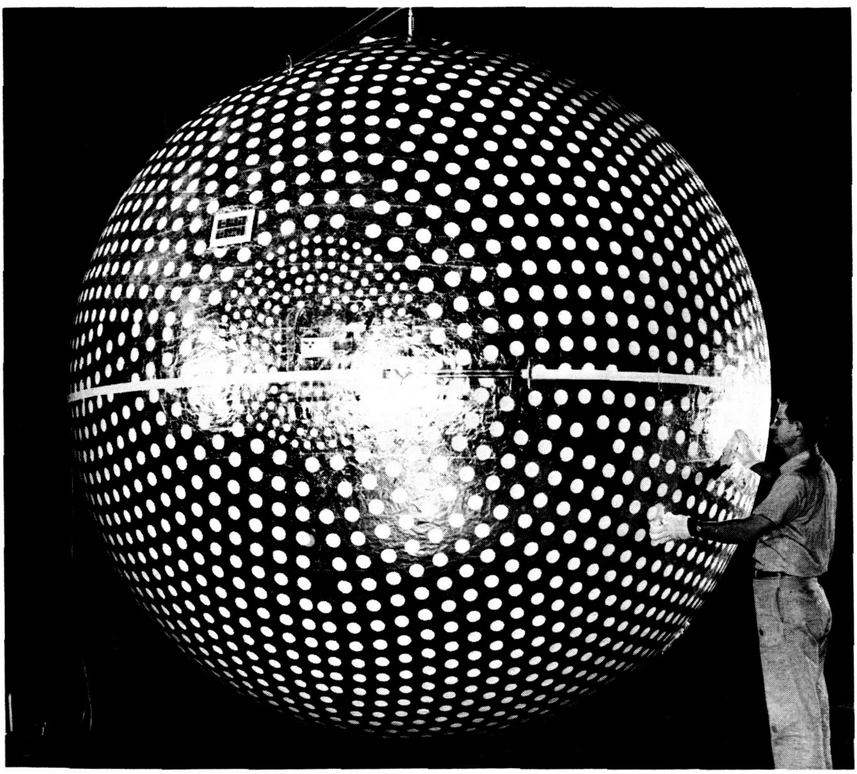


Figure 2–2. Explorer XIX—the Air Density Satellite.

The spacecraft—perigee 368 miles, apogee 1,482 miles, inclination to the equator 76.6°, and rotation period 116 minutes—carries a radio beacon. Since this beacon does not function, tracking is carried out by the worldwide Baker-Nunn camera network operated by the Astrophysical Observatory of the Smithsonian Institution.

Explorer XIX is observed in the same manner as Explorer IX which is still in orbit. Comparison of data observed simultaneously by the two satellites permits evaluations of the contribution of energetic particles to the heating of the atmosphere in the upper latitudes, as well as comparisons in low latitudes where heating results chiefly from solar electromagnetic radiation.

Sounding Rockets

NASA, during the second half of 1963, launched 40 sounding rockets carrying experiments in geophysics and astronomy above the earth's atmosphere. Scientific investigations by these versatile rockets cover as many areas of space science and technology as the experiments orbited aboard satellites. (Sounding rocket studies in meteorology are described in "Satellite Applications", ch. 3.)

Several outstanding sounding rocket launches of this report period included:

- Two flights to coincide with overhead passes of Alouette, the Canadian Topside Sounder Satellite launched September 29, 1962, with resulting good correlation of rocket and satellite data.
- Two other instrumented rocket flights to obtain information needed for the planned launching of an artificial comet, which involved releasing chemicals to study luminescent vapors like those released by a comet.
- A Canadian flight at about 40,000 feet during the solar eclipse of July 20 to study the effects of the eclipse on ionospheric properties.
- Another flight to test the experiments to be carried by the Mariner spacecraft being developed to fly by Mars in mid-1965.

Lunar and Planetary Programs

Structural test, thermal control, and midcourse simulation models of a Mariner spacecraft being developed to flyby Mars were built and tested during the last six months of 1963. In addition, the proof test model—identical to the spacecraft to be launched—was assembled and a comprehensive systems testing program begun.

This Mariner spacecraft is scheduled to be launched by the Atlas–Agena booster during the last quarter of 1964 and should intercept Mars in mid–1965 to record data on the surface and atmospheric conditions of the planet and also study the interplanetary space environment.

Pioneer

Scientific experiments and principal investigators for the first two Pioneer spacecraft were selected and preliminary designs of the various subsystems for the satellites completed during the report period. The 140-pound spacecraft will carry 30 pounds of instruments to measure magnetic fields, solar plasma, energetic particles, and other phenomena of interplanetary regions.

Instruments for the first two flights, scheduled for 1965, will include a magnetometer, plasma probe, cosmic ray telescope, micrometeorite detector, radio propagation sensor, and an energetic particle counter.

Ranger

During the report period Ranger A, latest in a series of spacecraft planned to collect data on the moon, underwent final preparations before its launching from Cape Kennedy early in 1964.

Designed to take TV pictures of the lunar surface vital to the Surveyor unmanned soft-landing spacecraft program and the Apollo manned lunar landings, Ranger A will carry six television cameras able to take over 3,000 pictures during the ten minutes prior to lunar impact. The last of these should be at least 10 times better than any available from earth-based photography, and could be good enough to identify surface formations and objects as small as a compact automobile.

Three other Rangers of this type, able to view more than one portion of the lunar surface, are being built and tested for launching in 1964 and 1965.

(Ranger A—successfully launched as Ranger VI on January 30, 1964—impacted the moon on February 2, within one second of the calculated time and within 20 miles of its aiming point. The spacecraft failed to take the planned photographs of the lunar surface just before it impacted. Investigations have not determined the specific cause of this failure. However, certain reasons for the failure were assumed and engineering tests and design changes were being made to preclude failure of this type in the three remaining Ranger flights.

(The seventh Ranger supplied thousands of lunar photographs on July 31, 1964. Details of its flight are given in the 12th Semiannual Report.)

Surveyor

Surveyor—a far more sophisticated spacecraft than either Mariner or Ranger—is being developed to make the first soft landings on the moon where it will survey possible sites for later manned landings and provide a better understanding of the lunar topography and environment. (See fig. 2–3.) The spacecraft will travel 240,000 miles from the earth in 66 hours and through a complex maneuver land softly on the moon.

Surveyor will transmit high-resolution TV pictures of lunar terrain and surface texture, measure the surface hardness and other chemical and physical properties, record lunar seismic activity ("earthquakes" on the moon), and observe meteorites near the surface.

Final assembly of the first flight spacecraft is scheduled to be started in the later part of 1964. During the last 6 months of 1963 components and subsystems of the craft were tested and refinements made. In addition, hovering and drop tests were made from a balloon to simulate a landing on the moon. These tests resulted in design improvements, as did tether tests conducted by suspending the test spacecraft from a tower. Environmental tests, including vibration and thermal-vacuum tests of spacecraft sectors, were also made.

A study was begun to determine whether it would be feasible for later Surveyors to carry small lunar-surface roving vehicles.

Lunar Orbiter

On August 30 NASA approved the Lunar Orbiter project to develop this country's first satellite of the moon. A prime con-

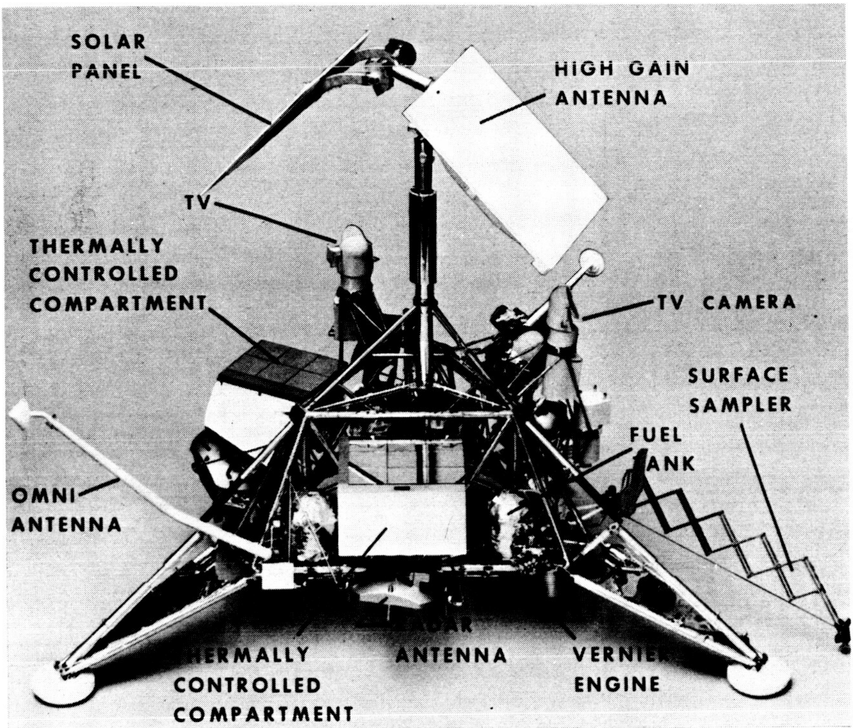


Figure 2–3. Surveyor spacecraft.

tractor for the project was selected and contract negotiations begun.

Lunar Orbiter's cameras will provide high-resolution photography of considerable areas of lunar surface for exploration and for selection of landing sites for unmanned and manner spacecraft. A secondary objective is the use of Orbiter for other scientific investigations of the moon, such as determining the shape of its gravity field from tracking measurements.

The first of five flight missions of the satellite is planned for the first half of 1966.

Bioscience Programs

Bioscientists of the National Aeronautics and Space Administration are responsible for basic research in the life sciences, biospace missions in search of extraterrestrial life, investigations of the effects of the space environment on living organisms, and basic biological research related to the support of man in space.

Among major accomplishments in the biosciences during the last 6 months of 1963 were the initiation of a biosatellite program consisting of six recoverable spacecraft, and noteworthy progress in developing promising devices to detect life on other planets and in interplanetary space.

Until the first of the biosatellites is launched in 1965, experimenters are essentially limited to studying the effects of outer space stresses on life forms as simulated in ground-based laboratories. Advances in this and related research are outlined in the paragraphs that follow, along with developments in life detection devices.

Biosatellites

Past biological space flight programs (such as NASA's Project BIOS—*B*iological *I*nvestigations of *O*uter *S*pace—and the Soviet's VOSTOKs) were primarily to explore the biological effects of cosmic radiation and weightlessness on various life forms carried aloft by rockets. During this report period the Agency's biosatellite program inaugurated a second generation of experiments on animals and plants in the space environment by establishing, through its Ames Research Center, a series of well-defined studies on these organisms which combines weightlessness with exposure to a radiation source flown aboard the satellite. (Fig. 2–4.)

The first of the six biosatellite flights is scheduled for near the end of 1965, with later ones at 3- to 4-month intervals. Each flight will be 3, 21, and 30 days long in a near-equatorial, roughly circular orbit at an altitude of about 230 miles. The spacecraft, launched from Cape Kennedy by Thor Delta boosters, will be recovered within 3 hours after reentry. (See the Ninth Semiannual Report, pp. 70.)

NASA's Space Science Steering Committee has reviewed and screened 175 experiments submitted by bioscientists from university, industry, and Government laboratories and selected 40 as high priority experiments for the biosatellites.

Environmental Biology

Until these biosatellites are available to environmental biologists, several NASA contractors and grantees are investigating

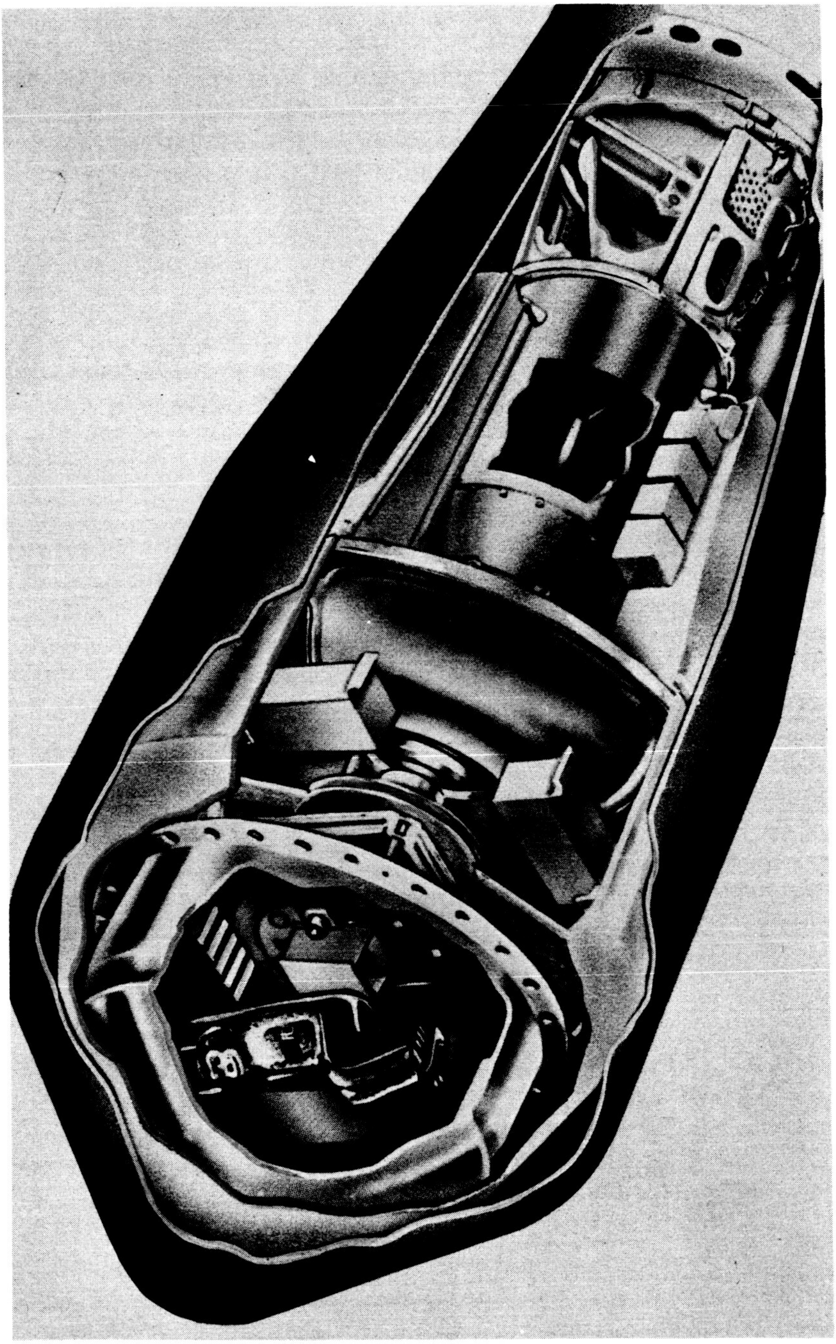


Figure 2–4. Artist's sketch of proposed biosatellite.

the effects of gravity, magnetism, radiation, and other outer space stresses on test subjects by simulating these conditions in ground-based laboratories.

For example, at the Argonne National Laboratory experimenters studying the effects of simulated weightlessness on plants by continually rotating them to compensate for the gravitational force found that some grew more slowly and had fewer and smaller leaves, others experienced greater growth in certain parts. These effects will later be compared with those that result from zero gravity in orbiting biological laboratories.

Research on high gravitational forces at the University of Texas Southwestern Medical School using a centrifuge showed that bacteria exposed to a high gravitational field for a day grew less, failed in cell division, and underwent general enlargement of cells and cell components. Human tissue culture cells reacted similarly when exposed to a heavy dose of radioactive cobalt.

High magnetic fields may protect future astronauts from radiation. This was demonstrated at the Naval Aviation Center when mice survived exposure to 300,000 gauss for a few microseconds in coils used for pulse forming of metals to be used in space.

Exposing Organisms to Manmade Atmospheres. — Although animals may develop and grow in the laboratory in an atmosphere almost free of nitrogen, studies at Ohio State University indicated that nitrogen may be needed for their normal adult life.

In other investigations, at Oklahoma City University, continuous exposure of rats to 100 percent oxygen for 25 days at a simulated 26,000-foot altitude resulted in a 10-percent decrease in their metabolism.

Men tested on a treadmill at Indiana University to determine their capacity to carry out work after their bodies were no longer able to supply oxygen were able to continue for only 8 minutes.

Effects of Simulated Martian Environment.—Many species of bacteria from deserts and mountain tops can survive exposure to a simulated Martian environment for as long as 10 months, research at the Illinois Institute of Technology and the University of California has shown.

Following up these studies, bioscientists have set out to define the maximum stress that biological organisms can stand in an environment and still survive and grow.

Life Support Systems for Spacecraft.—The Ninth Semiannual Report described a scientific breakthrough that came from the development of a biological system able to produce oxygen, food, and water from astronauts' waste products during prolonged space flights. This system—using the splitting of water into hydrogen and oxygen by electricity (electrolysis) with *Hydrogenomonas* (soil bacteria) which combine the hydrogen with the carbon of carbon dioxide from the astronaut—appears very promising.

Essential concentrations of oxygen and nitrogen, required temperatures, and other growth conditions needed for this life support system were established during the last 6 months of 1963. In addition, an electrolysis unit that is nearly automatic was designed and built.

The Connecticut Agricultural Experiment Station has screened various plants for use in life support systems and selected corn, sugar cane, and sunflowers. The amount of leaf surface from these plants needed to support an astronaut was determined to be between 100 and 130 square feet.

In related research environmental biologists at the University of Maryland developed an automatic apparatus for the continuous culture of *Chlorella* algae. The apparatus conserves and recycles all water, adds nutrient, and removes excess algae cells.

Behavioral Biology

Spacecraft designers do not know how much artificial gravity needs to be provided astronauts or other life forms if they are to function efficiently in space. For this reason, man's response to prolonged exposure to gravity levels between a constant 1 g and weightlessness must be determined.

At the University of Kentucky bioscientists studying gravity preference of small animals are examining the possibility of modifying gravitational preference by prolonged exposures to altered gravity environments. Mice, free to move about between gravity levels of 1 to 3.2 g's, are being studied in a rotating gravity selection device. Figure 2–5 is a high speed photograph of this device showing concentric circles that represent different gravity fields.

The university experimenters use other special centrifuges providing extended exposure of mice to gravity above 1 g during breeding. Inflight experiments will be required to explore gravity levels between zero and 1 g.

Other studies are being conducted jointly by NASA and the

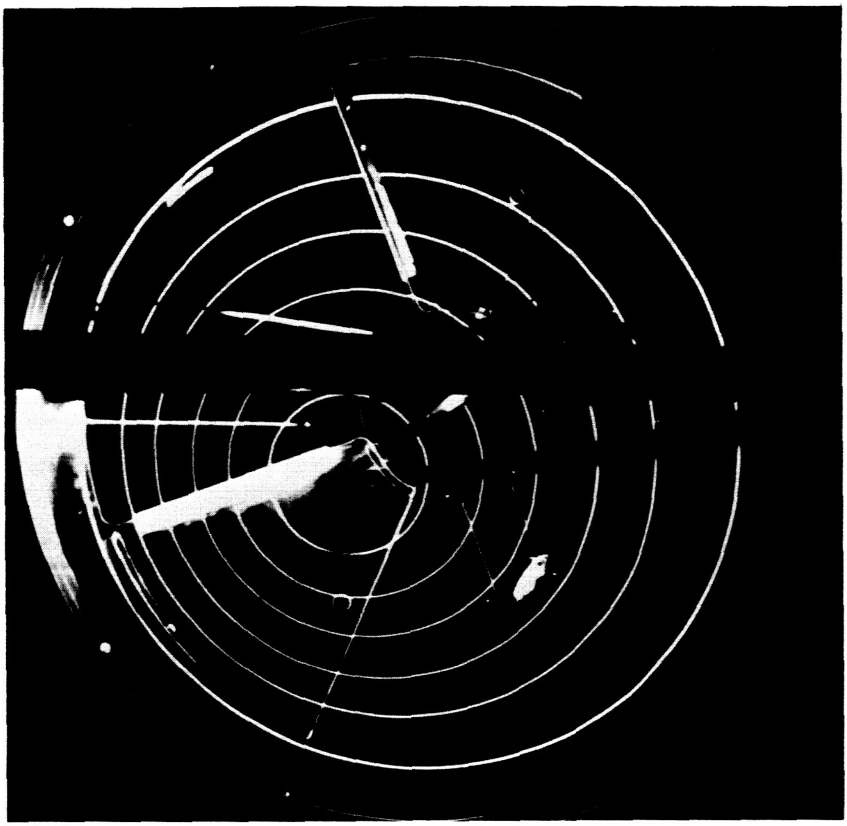


Figure 2–5. Selection of gravity levels in mice.

Department of Defense to determine if weightlessness can cause space sickness, loss of equilibrium, and other disorders. Very limited evidence from space flights of men and animals suggests that these "vestibular" disorders may result.

One experiment to explore this possibility will use the apparatus shown in figure 2–6 to observe and measure the responses of an animal in space to see if it develops space sickness. Performance tests will access the animal's orientation, locomotor behavior, and coordination.

To aid in interpreting the inflight data, the Ames Research Center is using cats and monkeys to investigate the functions of the vestibular system as they relate to posture and movement, and to learn how acceleration, rotation, and weightlessness affect this system.

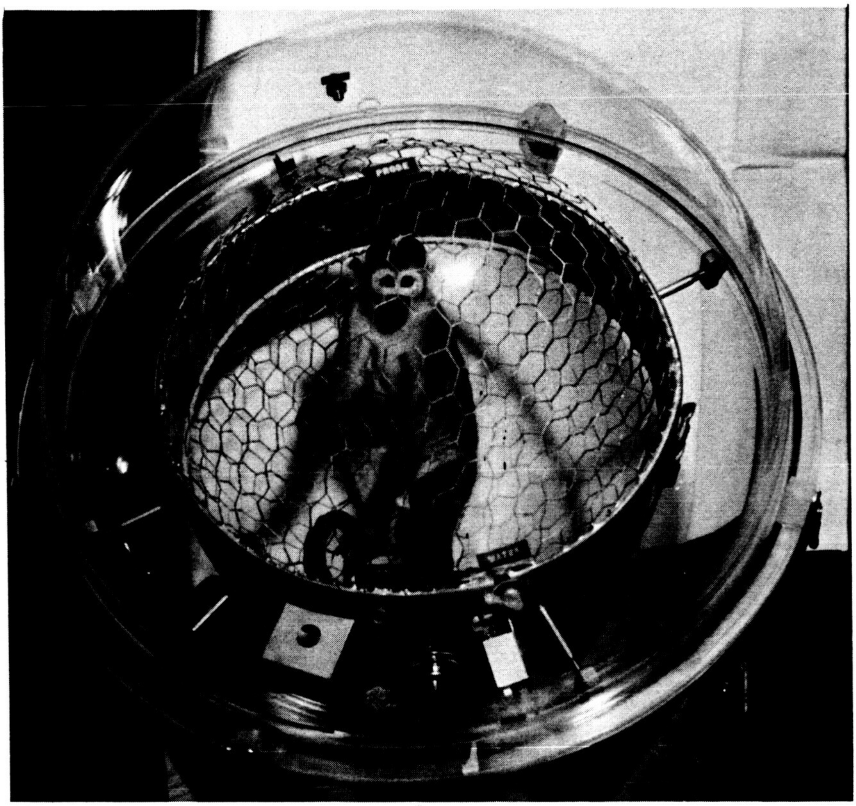


Figure 2–6. Apparatus determines if monkey suffers from space sickness.

Related investigations at the Ames Center have demonstrated that the behavioral capacities of primates remain intact when they are confined for a year or longer under controlled conditions (fig. 2–7.)

Exobiology

In the field of exobiology (the study of extraterrestrial life) substantial advances were made during this report period in developing two miniature life detection devices—Multivator and Gulliver.

Multivator, designed to chemically analyze Martian soil or dust, is 10 inches long and 2¾ inches in diameter and weighs 30 ounces. (Fig. 2–8.)

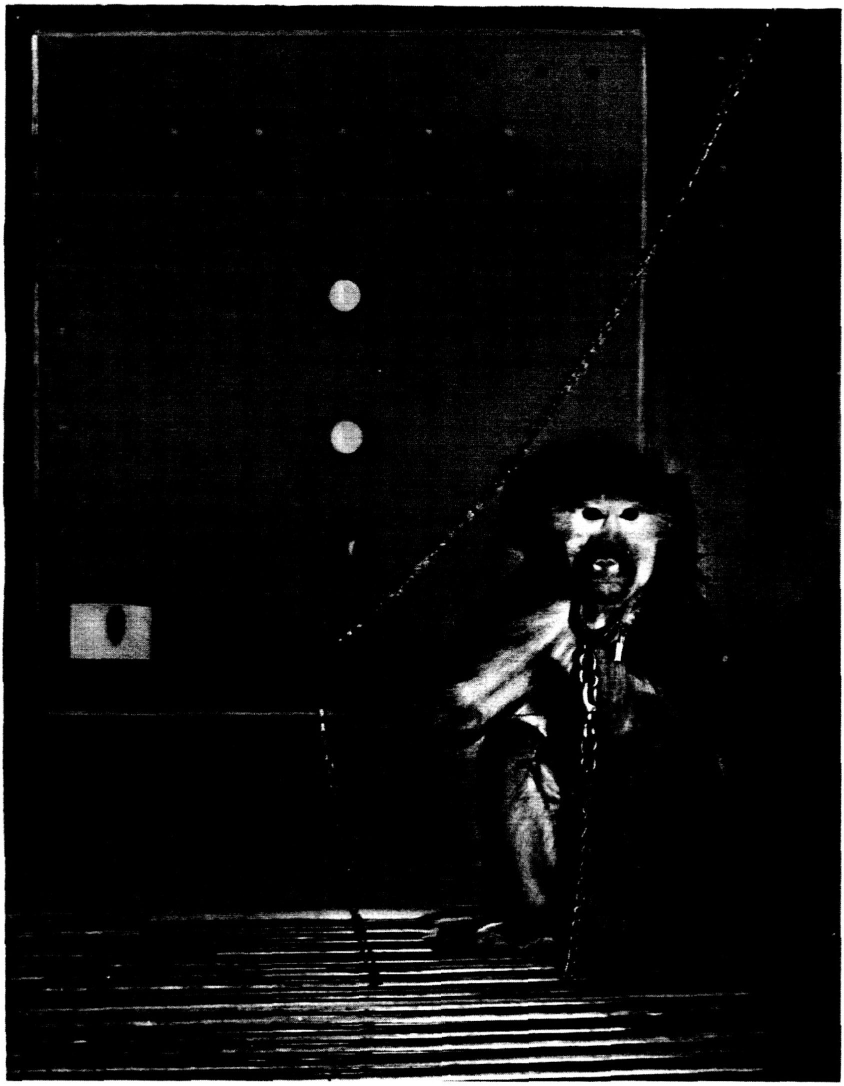


Figure 2–7. Baboon in isolation chamber.

The experimental heart of this miniature biological laboratory is a wheel of 15 experiment chambers shown in fig. 2–9.

Gulliver is a radioisotope biochemical probe about as large as a candy jar that weighs only 1½ pounds. This remote life sampler uses a tethered projectile to capture the sample and draw it into

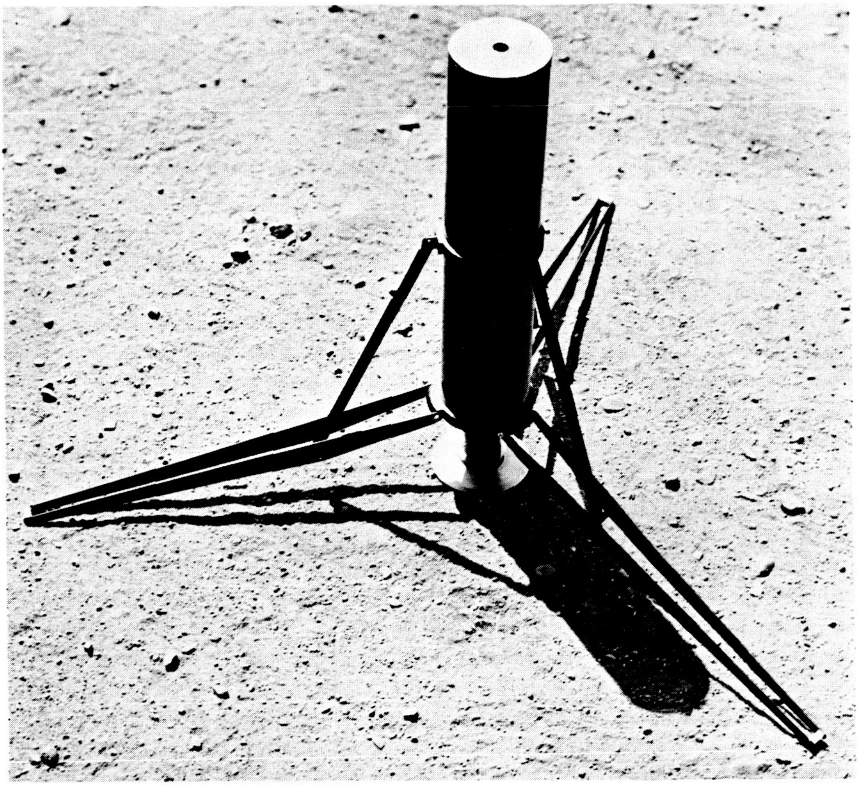


Figure 2–8. Latest Multivator model.

a growth medium containing sugar labeled with radioactive carbon (C^{14}). Organisms then ferment the sugar and produce carbon dioxide gas; a radiation counter measures the C^{14} in the gas, telemetering the data to earth.

Planetary Quarantine

During the last 6 months of 1963 a planetary quarantine program was established to prevent the transmission of earth's life forms to Mars and the other planets. Plans also were inaugurated to prevent any return of contamination from these planets to the earth. Long-period, low level heat treatments (24 hours at 275° F.) coupled with hospital cleanliness maintained at all levels of assembly should provide sterile landing capsules. However, some heat sensitive parts will require specially designed treatment.

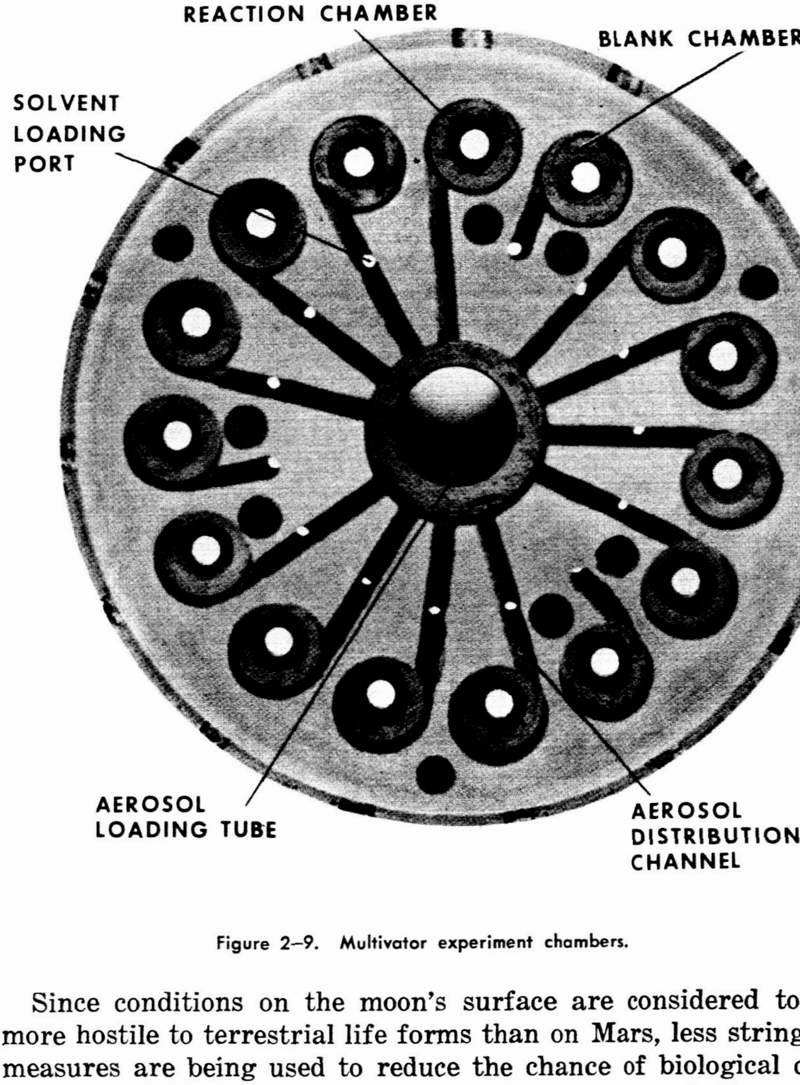


Figure 2–9. Multivator experiment chambers.

Since conditions on the moon's surface are considered to be more hostile to terrestrial life forms than on Mars, less stringent measures are being used to reduce the chance of biological contamination on lunar landers (such as the Ranger series.)

Fig. 2–10 shows Gulliver on the floor of a simulated capsule with the nose cone removed and the sticky string wound into the device. The probe has undergone successful sensitivity tests in such rugged environments as Death Valley—282 feet below sea level in Eastern California—and the Salton Sea at about the same depth in the southern part of the state. At the other extreme the device was tested at 12,000 feet on a rocky wind swept prominence near Mount Whitney (also in California.)

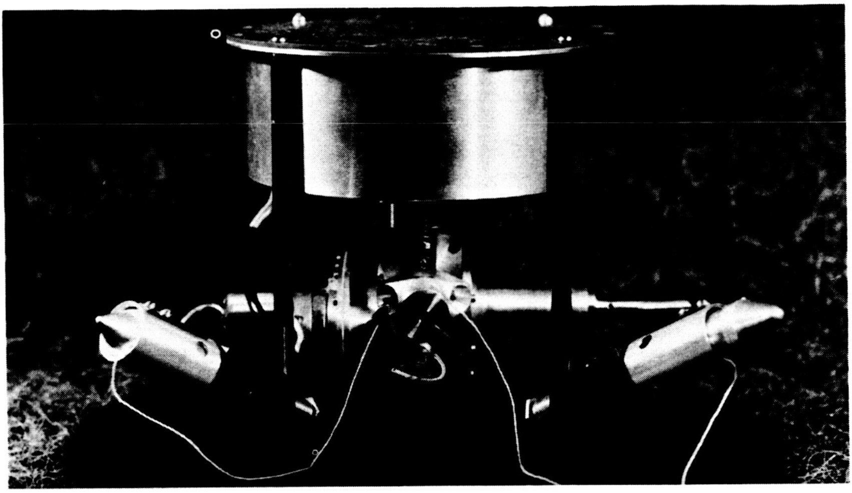


Figure 2–10. Gulliver life detection device.

Physical Biology

A study in nutrition for manned space missions and animal experiments in space was conducted during this report period.

Fifteen volunteer prisoners fed a chemically defined liquid diet of amino acids, vitamins, carbohydrates, and necessary minerals for a 120-day period experienced neither appreciable weight loss nor major medical difficulties during the test period. (Nine of the original group of 24 dropped out of the experiment for personal reasons. See "synthetic diets," Eighth Semiannual Report, p. 77.)

A cubic foot of this diet (including 50 percent water) is designed to supply 2,000 calories a day for a month.

Manned Space Science

Scientists throughout the country in the late summer and fall of 1963 responded to a NASA inquiry by proposing experiments to be conducted in connection with the early research and development missions of the two-man Gemini spacecraft.

(*Note:* "Laboratory-Produced Lifelike Cells" (p. 66, Ninth Semiannual Report to Congress) indicated that synthesized cell-like microspheres possessed cell walls, nuclei, and reproduce. These terms are incorrect analogies to actual "living cells." This section should be ignored until this interesting work is further developed and can be presented in greater detail.)

Following this highly favorable response, the Agency, in cooperation with the Nation's scientists, broadened its science programs to include the planning and development of scientific experiments for manned space flights which will make maximum use of the astronauts' ability to function in space. These investigations will include scientific exploration of the moon by Project Apollo astronauts. NASA, in cooperation with the National Academy of Sciences, is determining standards for the selection of scientist-astronauts.

Since a number of scientists are interested in the potential of a manned orbiting research laboratory, NASA has undertaken studies to determine the expected scientific values and spacecraft requirements associated with such research.

Medium Launch Vehicles

The Scout, Delta, and Atlas-Centaur medium launch vehicles were used by NASA to orbit spacecraft in its space science and applications programs during the report period.

Scout

Three Scout launches were made—the first two, a NASA reentry experiment and an orbital mission of the Defense Department, were unsuccessful. The cause of these failures was determined and a third launch resulted in the successful orbiting of Explorer XIX in December (p. 72.) This Air Density Satellite marked the 10th Scout launching and the first time that a NASA spacecraft was launched from the Pacific Missile Range, Point Arguello, Calif.

Delta

Delta accomplished three more launches, bringing its total to 21 successes in 22 attempts.

Placed into orbit were: Syncom II on July 26 (p. 99); Explorer XVIII on November 26 (p. 70); and TIROS VIII on December 21 (p. 90.)

The Explorer XVIII launch represented the first use of the X–258 solid rocket motor as the third stage for Delta.

Agena

The NASA–Air Force jointly funded Agena improvement program, described in the Ninth Semiannual Report, proceeded slightly behind schedule. The first Air Force launch of this improved vehicle is scheduled for the second quarter of 1964 rather than the fourth quarter of 1963 as previously reported. This delay will not affect the Agency's plans to use this vehicle for a Martian flyby of the next Mariner spacecraft late in 1964.

Communications Satellite Launch.—Preparations are being made for a Thor-Agena vehicle to place the passive communications satellite Echo II in orbit in January 1964. The launch vehicle, as well as the special TV system to monitor spacecraft separation and balloon injection and inflation, were on schedule. (The 135-foot, 500-pound improved rigid sphere was successfully orbited on January 25.)

Ranger Lunar Launch.—The Atlas and Agena vehicles assigned to the lunar exploratory flight of Ranger VI were delivered to Cape Kennedy and preparations were on schedule for a launch early in 1964. (See p. 75.)

NASA–Air Force Management Relationship.—Provisions of the new working agreement between NASA and the Air Force to permit greater participation by the Agency in Air Force improvement and development programs for the Atlas–Agena and Thor–Agena vehicles are being carried out with minimum disruption to operations.

The Lewis Research Center has negotiated 10 contracts for studies, basic vehicles, and mission modifications that were formerly handled through Air Force contracts. NASA's scientists and engineers serve on boards charged with the responsibility for changes in configurations for the Atlas, Thor, and Agena vehicles and take an active part in reliability and quality assurance programs for these vehicles.

By a mutual agreement of NASA and the Air Force launch services contracts at Cape Kennedy will not be transferred to the Agency until the current Air Force program is "phased out" (planned for late in 1964.)

Atlas-Centaur

On November 27 an Atlas–Centaur was successfully launched from Cape Kennedy in a second test of the vehicle's performance, marking the first successful flight of a liquid-hydrogen fueled vehicle in the free world. This major step forward in the Nation's space program followed a failure of the Centaur stage in May 1962 (Seventh Semiannual Report, p. 23) and came about as a result of appreciable changes in the program after this failure.

Atlas-Centaur is being developed to carry Surveyor spacecraft to the moon and advanced Mariner craft to Mars and Venus. Liquid hydrogen technology of Centaur will also support the development of upper stages for Saturn's lunar exploration launches and be adapted to future vehicles.

In the November launch the entire Centaur stage of about 5 tons was placed in the planned earth orbit. All vehicle systems operated well and all of the objectives of the flight were attained.

Extensive ground tests of the vehicle continue. The next flight test is scheduled for the spring of 1964. Surveyor flights should begin early in 1965.

Satellite Applications

As 1963 drew to a close there was a growing awareness throughout the world of the invaluable data being supplied by the TIROS spacecraft, as well as by the mounting number of sounding rockets that explore the earth's environment. This meteorological satellite system promised an increasing volume of data to serve research scientists here and abroad for years to come.

So, too, information services around the globe began to recognize the tremendous potential of communications satellites as a versatile new medium. This fact was well demonstrated when, at the request of the TV networks, NASA made Relay available to provide viewers in Europe and Japan with coverage of the events surrounding the assassination of President Kennedy.

Meteorological Programs

The Agency's meteorological satellites and sounding rockets continued to contribute to the development and improvement of space technology, including sensors and subsystems, which will provide data for use by meteorologists.

During the last 6 months of 1963 research and development flights furnished research and operational meteorologists with the vital data outlined in the following accounts.

TIROS

TIROS VIII, launched on December 21, carries the first experimental Automatic Picture Transmission (APT) subsystem as part of extensive qualification tests prior to being installed aboard the polar-orbiting Nimbus. (Fig. 3–1). Its launching marked the eighth consecutive success in this series of meteorological satellites, as well as the 21st successful launch of a Delta vehicle in as many attempts. Along with the APT subsystem, orbited in place of other sensory subsystems included on earlier spacecraft of this

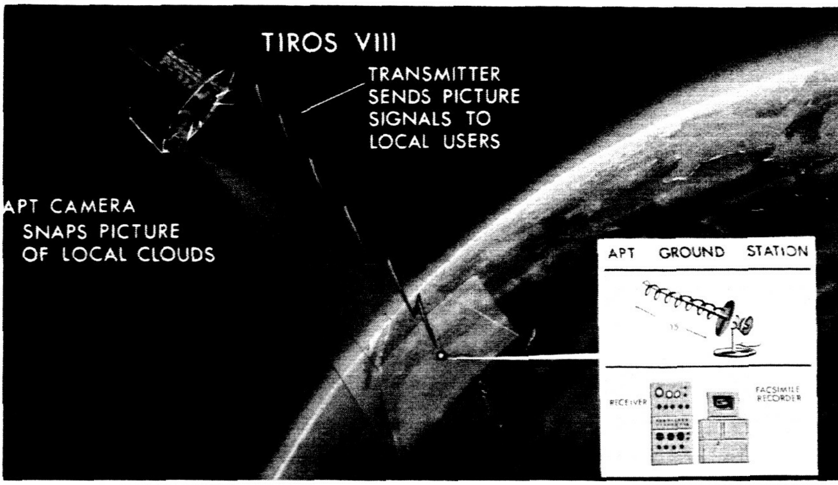


Figure 3–1. TIROS tests Automatic Picture Transmission subsystem.

design, TIROS VIII carries a standard TV camera and circuitry for magnetic tape recording and television transmission.

The APT subsystem is planned to enable meteorologists using relatively simple equipment to receive local cloud cover pictures as the satellite passes overhead rather than depending on data relay from one of several large command and data acquisition stations. This direct local readout capability, which is expected to be particularly useful in remote areas, is possible through the use of relatively inexpensive equipment (costing less than $35,000 a set.)

The direct local readout station uses a 15-foot helix as an antenna. A typical ground station also consists of a commercially available radio receiver and a standard photofacsimile machine.

A complete picture cycle of the APT subsystem on the TIROS satellite takes about three minutes for each picture, with the APT ground station receiving up to three pictures a pass depending on the satellite's elevation angle. The spacecraft must be within a 1,500-mile radius of the station for reception.

The 108° lens used in the APT subsystem can photograph an area about 820 miles on a side when the satellite is looking directly toward the earth. An electromagnetic shutter in a 3-millisecond exposure produces an 800-scan line picture on the photosensitive surface of a special 1-inch diameter vidicon. A timer programs the equipment for continuous cycles of prepare, expose, develop, and direct readout for approximately 30 minutes of each orbit. The prepare-expose-develop cycle takes place the first 8 seconds of each 208-second picture cycle. The remaining 200 seconds are used to readout the photograph at a scan rate of four lines a second.

TIROS ground stations are at NASA's Wallops Island (Va.), Fairbanks, Alaska, and Point Mugu, Calif. The Fairbanks station, newest in this tracking network, began operating during September and has received photographs from TIROS VI, VII, and VIII.

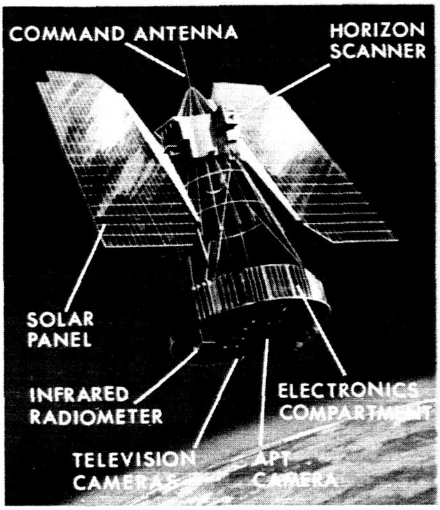
In addition to TIROS VIII, TIROS VI and VII operated during the last half of 1963. TIROS VI, launched September 18, 1962, continued transmitting pictures from its two TV cameras until October 11, 1963, setting a new longevity record for meteorological satellites. This sixth TIROS produced about 60,000 meteorologically useful TV cloud cover pictures, as well as having discovered Typhoon Karen and Hurricane Arlene in 1962 and Tropical Storms Hester and Jennifer in 1963. Data transmitted were used by the Weather Bureau as the basis for over 2,100 cloud cover analyses and 361 storm warnings.

TIROS VII produced 37,183 meteorologically useful cloud cover pictures in 6 months and discovered five hurricanes over the Atlantic Ocean. Its launching (June 19, 1963) was twice delayed due to the unexpected extended performance of TIROS V and VI.

Nimbus

Nimbus, based upon knowledge gained from the TIROS flights, was planned as a meteorological observatory in space. (Fig. 3–2). This advanced weather satellite will: (1) be earth-oriented at all times; (2) have the capability of providing complete global coverage daily; (3) supply nighttime cloud cover data by using special high resolution infrared radiometers; (4) permit users equipped with relatively simple, inexpensive ground stations to receive local cloud cover pictures directly from the spacecraft; and (5) be flexible enough to adapt to future instrumentation with minimum difficulty.

The Nimbus prototype was assembled and integrated during the last 6 months of 1963. Its rigorous testing neared completion. The first flight model underwent assembly, integration, and tests prior to an initial launching planned for 1964.



GROSS WEIGHT	750 LBS.
INSTRUMENT WEIGHT	150 LBS.
SENSORS	3
POWER	400 WATTS
STABILIZATION	ACTIVE 3 AXIS
DESIGN LIFE	ONE YEAR
LAUNCH VEHICLE	THOR-AGENA
ORBIT	CIRCULAR 575 MI. INCLINATION 80° RETROGRADE
PLAN	FIRST FLIGHT 1964

Figure 3–2. Nimbus.

A first launch was expected to take place during the winter of 1963 (Ninth Semiannual Report, pp. 79.) However, tests revealed electrical interference between the subsystems of the assembled prototype which were successfully tested individually. (This type of interference frequently occurs when complex electronic equipment is first assembled, since the effect of one subsystem on another is difficult to predict until they are mated.)

Required changes were made and the model successfully tested. Prototype and flight model test procedures and schedules were reviewed and revised to allow the earliest possible launch date. The flight unit is undergoing assembly and subsystem tests as individual units.

On October 4 it was announced that the Weather Bureau would not use the current Nimbus configuration as the basic instrument in the national operational meteorological satellite systems since further research and development was needed before operational data requirements could be met within resources limitations for a fully operational system. Accordingly, an interim system based on TIROS technology will provide minimum operational data needed until the fully operational system can be developed. Meanwhile NASA is continuing with Nimbus research and development to develop new devices, techniques, and subsystems, and provide the more sophisticated data basic to better understanding and interpretation of meteorological phenomena. Further, this work will advance the technology required to make the fully operational meteorological satellite system possible.

Sounding Rockets

Continuing its studies from Wallops Island, Va., of the dynamics and structure of the atmosphere at altitudes ranging from 20 to 70 miles, NASA, during the report period, launched one large meteorological sounding rocket carrying a grenade experiment and another a pitot tube experiment. Four grenade experiments were also launched by the Agency from Kronogård, Sweden near the Arctic Circle in a cooperative program to investigate noctilucent (night shining) clouds.

Temperatures as low as —143° C. were recorded from the Swedish launches at a height of about 50 miles when these clouds occurred. This is about 20° colder than when there were no noctilucent clouds and about 40° colder than previously measured at a similar altitude over Fort Churchill, Canada.

Ninety smaller meteorological rockets were launched from Wallops Island to provide measurements from an altitude of 20 through 40 miles above the earth—25 of these were for the Navy. The remaining 65 were launched for NASA as part of the program to improve and develop a small meteorological sounding rocket system. These launches were coordinated with launches by the Army, Navy, and Air Force from other locations to provide range support and synoptic data for upper atmospheric meteorological research.

Cooperating with India and Pakistan to provide meteorological sounding rocket observations for the International Indian Ocean Expedition of 1964, NASA loaned these countries ground equipment and trained their personnel in observational procedures and equipment maintenance. Australia, England, France, Italy, and other countries were also invited to participate in a coordinated series of small rocket launches in the Indian Ocean area in connection with this expedition.

Supporting Research and Technology

Providing a basis for improvements in present meteorological flight projects and implementing future projects, NASA continued its supporting research and development program during the last 6 months of 1963.

Several examples of this type of research and development follow.

Interrogation and Recording Subsystem for Meteorological Satellites.—A technique under study would use these satellites to acquire data from within the earth's atmosphere by interrogating automatic sensing platforms (such as automatic weather stations and oceanographic buoys.)

Information gathered by this method would help solve the problem of obtaining meteorological data over extensive areas of the earth where such data are sparse.

Meteorological Systems Aboard Synchronous Satellites.—Studies were undertaken to provide valid background for selecting experiments to be conducted in orbit. Particular attention was given to research and development into items requiring long lead times. The very wide range of image brightness involved in taking pictures of the full disk of the earth emerged as a difficult problem.

Highly Eccentric Orbit for Modified TIROS.—An apogee at about synchronous altitudes and a perigee of about 200 miles should, for the first time, allow meteorologists to obtain satellite cloud cover data of a particular area continuously for several hours. The study results are being applied directly to the flight of TIROS K (11th in the research and development series) which is planned to perform in this manner.

Advanced Meteorological Sensor.—An image orthicon (day-night) TV camera is under development that has a broad dynamic range and can take photographs in full sunlight, or at about one-fourth moonlight, without injury to the device. (Fig. 3–3.) In addition, although sunlit photographs are brighter, detail and gray scale are close to uniform.

Communication and Navigation Programs

The report period saw Africa, South America, and Japan linked with the United States for the first time through experiments in the transmission of voice, teletype, and facsimile, and Japan with the United States by TV—all via communications satellite.

NASA also furthered research: to make available the technology needed for operational communications systems; to assess the potential and insure the fullest possible exploitation of satel-

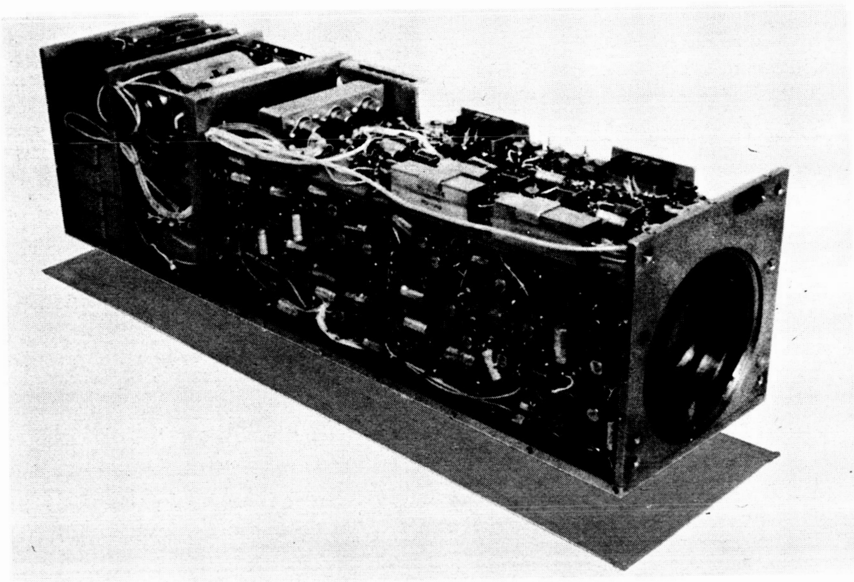


Figure 3–3. Day-night TV development.

lites for communications needs other than those normally provided by common carriers; and to meet its responsibilities under the Communications Satellite Act of 1962.

Close cooperation and mutual support continued between the Agency and the Department of Defense. Specifically, NASA's specialists in communications participated in the activities of the Unmanned Spacecraft Panel and in the Technical Committee on Communications Satellites. The Defense Department supplied Project Syncom with a communications ground station complex of three shore terminals and a terminal aboard the USNS *Kingsport.*

Results of NASA's current experimental programs, and the capabilities of available launch vehicles as they apply to plans of the Communications Satellite Corp. for a global communications system, were discussed "at the working level" with the corporation. (In accordance with the Communications Satellite Act of 1962 NASA is to advise the Federal Communications Commission on technical matters, cooperate in research and development with the Communications Satellite Corp. established by the act, and furnish the Corporation—on a reimbursable basis—satellite-launching and associated services.)

Space Radiocommunications Conference

Specific frequency bands for satellites were allocated at the Space Radiocommunications Conference of the International Telecommunications Union held in Geneva, October 7 through November 8, 1963. A total of 2,800 megacycles (between 3,400 and 8,100 megacycles per second) was allocated for use by communications satellites systems on a shared basis with terrestrial line-of-sight radio relay systems. Frequencies were also provided for meteorological and navigation satellite systems space research, telemetry, tracking and command, and for radioastronomy. In addition, provision was made for use of satellite-borne facilities in certain aeronautical communication and navigation bands.

Time Delay and Echo Tests

An old problem of telephone engineers is suppressing delayed echoes in long communications circuits. Echoes with delay times of an appreciable fraction of a second reduce the efficiency of circuit use by confusing telephone users and slowing down communications.

Satellites for intercontinental communications have revived interest in this problem, since the round-trip delay time through a satellite circuit is appreciably greater than that for earth-based circuits.

Numerous laboratory tests to evaluate the effect of various conditions of delay and echo on telephone users were made. Although some of the tests suggest that these effects might degrade telephone service via synchronous satellites, the test results are inconclusive. Nevertheless, time and delay limits were recommended to the Consultative Committee for Telephone and Telegraph, International Telecommunications Union, which, if adopted, would curb the commercial uses of synchronous communications satellites.

In July, NASA, the Federal Communications Commission (FCC), the Communications Satellite Corp. (ComSat Corp.), and the American Telephone & Telegraph Co. agreed that additional tests should be carried out under more realistic conditions. Accordingly, in October, NASA, the ComSat Corp., and the A.T. & T. in cooperation began more comprehensive tests involving international users. The tests—also requiring British and French cooperation—include use of regular trans-atlantic cables, as well as the Telstar and Relay communications satellites (subject to arrangements with the FCC.)

Results of this program are expected to be available during the second quarter of 1964.

Active Communications Satellites

The last 6 months of 1963 witnessed several achievements with active communications satellites. Telstar II operated with near total success; Relay I performed beyond its designed lifetime of 1 year; and Syncom II became the world's first satellite to be placed into synchronous orbit and successfully maneuvered into position.

Telstar.—Improvements growing out of experience with the first Telstar resulted in a more reliable Telstar II. The satellite continued to link Europe with North America—operating successfully except for a brief period (July 16–August 12.) Telstar II's highly elliptical orbit, apogee 6,708 miles and perigee 603 miles, minimized radiation damage and increased mutual visibility. Radiation measuring devices aboard the spacecraft demonstrated great sensitivity and six additional telemetry channels supplied new data on the space environment.

Relay.—The first Relay spacecraft operated with success beyond its design goal of 12 months, with the exception of 25 days during the initial weeks of its life. (Described in the Eighth and Ninth Semiannual Reports.) Its success in linking North America to South America, Europe, and Asia paved the way for early operational systems. Relay I by the end of the year neared 3,000 orbits, 300 hours of wideband operation, 700 transponder operations, 2,000 experiments, and 200 demonstrations.

West German and Japanese stations joined the Relay network on October 23 and November 22, respectively, and various scientific demonstrations and experiments took place.

An improved Relay was readied for launch. (This Relay II was successfully launched from Cape Kennedy on January 21, 1964.) Based on Relay I's year in orbit, seven modifications were incorporated into this satellite to improve its reliability and performance. Three improvements relating to power regulation and control circuitry were designed to prevent a loss of onboard power as was caused by an uncontrollable voltage regulator circuit during the first days of the orbiting Relay I.

Syncom.—Launched on July 26, 1963, Syncom II has demonstrated that a communications satellite can be controlled in synchronous orbit and maneuvered to a preselected station. During the report period the spacecraft:

- Relayed at synchronous altitude the first multichannel voice communications, multichannel teletype, simultaneous voice and teletype, and facsimile;
- Set a new record for satellite communications—1,575 hours involving more than 5,000 experiments and special tests (as of February 29, 1964) ; and
- Carried voice traffic between Africa and North America which was further transmitted to South America via the Relay satellite.

Teletype messages and facsimile pictures were relayed between the station aboard the USNS *Kingsport* in Lagos Harbor, Nigeria and the Lakehurst (N.J.) ground station. President Kennedy and Prime Minister Balewa of Nigeria, on August 23, formally inaugurated the Syncom satellite with the first public telephone call between heads of state via satellite.

Other demonstrations of the last 6 months of 1963 included: Data sent from the oceanographic research ship *Geronimo* in the Gulf of Guinea to the Bureau of Fisheries in Washington, D.C.; transmission of President Kennedy's United Nations speech from New York to Nigeria via Syncom; and a picture-only experimental telecast between Fort Dix, N.J. and Andover, Maine. In addition, in late October, telephone calls were arranged from delegates to the Space Radiocommunications Conference at the International Telecommunications Union in Geneva to diplomatic members of their countries' delegations in Washington and at U.N. Headquarters in New York. About 100 calls—relayed through the USNS *Kingsport* ground station berthed at Rota, Spain—were placed for representatives from 27 countries and 10 international organizations.

Syncom II drifted westward during this report period due partly to the triaxiality of the earth. This drift was slowed by a nitrogen and peroxide system of jets to 0.08° a day at one period and later, on November 27, to 0.0045° a day. Triaxiality (the unequal distribution of the earth's bulge at the equation) is of great interest to geodesists around the world who are studying the satellite's deviations from orbit.

Syncom II, in synchronous orbit tracing a long narrow figure 8 on the face of the earth, was nearly stationary at its equatorial crossing of 55° West Longitude but extends between 33° North and South Latitudes. A stationary satellite must have a booster vehicle able to remove all traces of this North-South motion by reducing the inclination of the spacecraft's orbital plane to zero while placing the satellite in a synchronous orbit. In mid-1963 the availability of a thrust-augmented Thor provided further evidence that a Delta vehicle so augmented could possibly place a spacecraft into a stationary orbit yet be reliable and comparatively economical.

Syncom III, scheduled for launching in the middle of 1964, will take advantage of this capability. In addition, new types of solar cells have increased the satellite's resistance to the radiation damage of outer space.

Passive Communications Satellites

Project Echo has demonstrated that a large balloon may be launched, erected, pressurized in orbit, and used as a radio relay by passive reflection.

Echo I marked its third anniversary in space on August 12. Wrinkled, partially deflated, and no longer an effective communications relay medium, its reflective characteristics continue to be monitored.

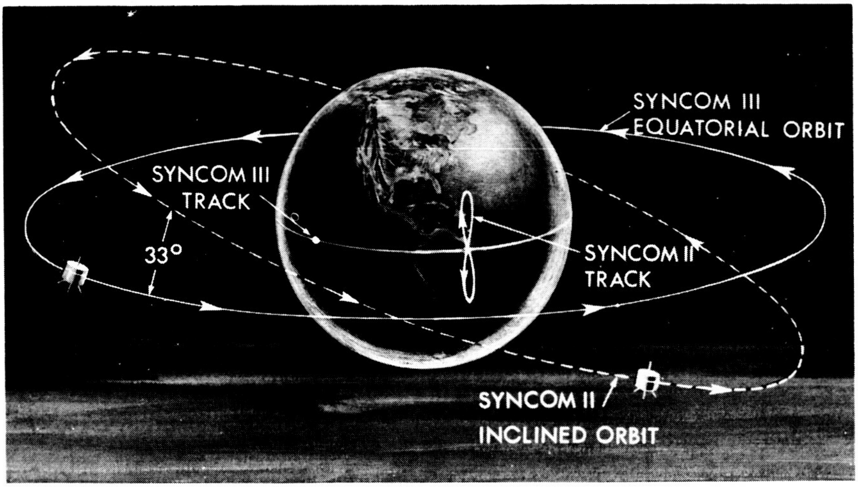


Figure 3–4. Orbits of Syncom II and III.

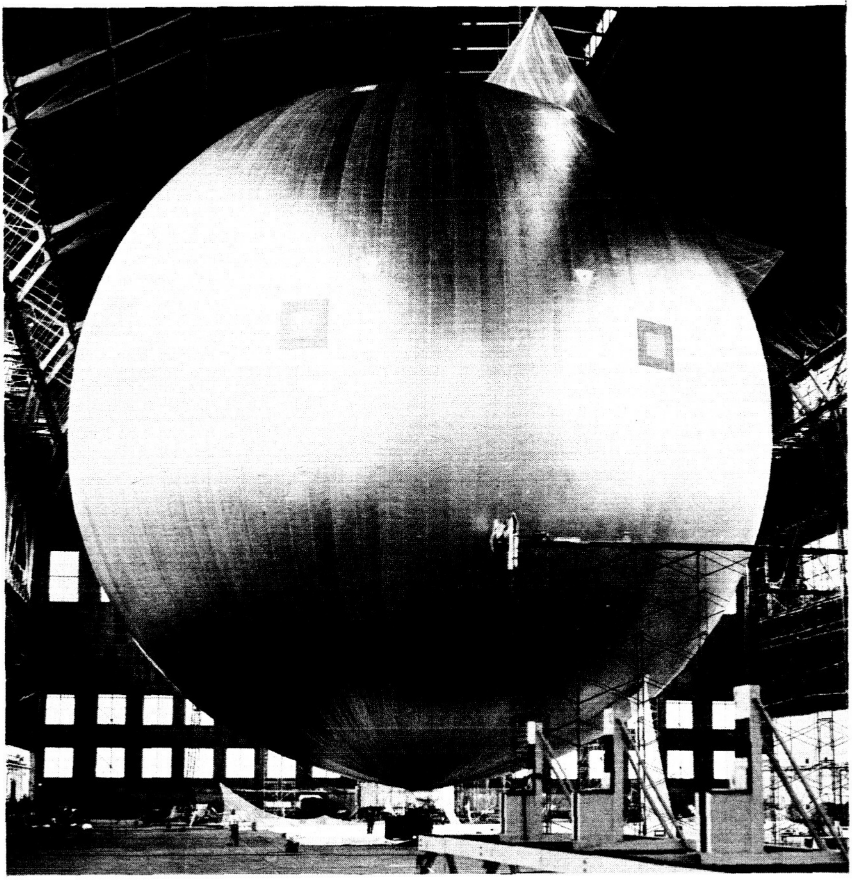


Figure 3–5. Echo II inflation test.

Echo II, an improved rigid sphere 135 feet in diameter weighing 570 pounds—described in Semiannual Reports Five through Nine, was being readied for launch. (The satellite was successfully orbited on January 25, 1964.) Balloon improvements for Echo II were developed through two ballistic launches and static inflation tests. (See the Ninth Semiannual Report.) These improvements include: A system to control the inflation rate of the sphere by using a set of porous bags containing the inflatant chemical pyrazole; new gore cutting and sealing techniques; canister bolsters to prevent balloon shift during launch accelerations; and tracking beacons to monitor internal balloon pressure and skin temperature.

A TV transmitter will monitor the spacecraft's erection after ejection; a van housing mobile equipment in Pretoria, Union of South Africa, will receive these transmissions.

Echo II is to be used by Russian scientists in the U.S.S.R. to receive radio signals transmitted from England in limited joint communications experiments resulting from a cooperative agreement on space projects between the United States and the Soviet Union announced on August 26, 1963.

Navigation Satellites

Navigation satellite research, closely related to and combined administratively with research for communications satellites, is investigating the feasibility of a nonmilitary satellite system to serve as an air-sea navigation, rescue, and traffic control aid. Undertaken during the last 6 months of 1963, these investigations are closely coordinated with all Government agencies responsible for the aids.

Incomplete in 1963, the studies indicate that such a system using simple surface and airborne equipment warrants consideration. Accordingly, the Advanced Technological Satellites Program (described in the next paragraphs) will provide for a navigational experiment.

Advanced Technological Satellites

Plans for Advanced Syncom—described in the Ninth Semiannual Report—were reoriented to supply an expanded testbed for advanced technological experiments (in addition to communications testing) required by NASA and the Defense Department for 24-hour satellites. The reoriented program uses technology developed under Advanced Syncom and is called the Advanced Technological Satellites Program. An objective of the program is to develop and flight-test the advanced technology required to place a stabilized and oriented, long-lived station-keeping spacecraft into 24-hour orbit.

The Advanced Technological Satellites spacecraft may also include experiments in meteorology, highly directive spacecraft antenna, infrared earth sensors, radiation environment, damage from radiation, navigation, and multiple access (satellite access by more than two ground stations at once.)

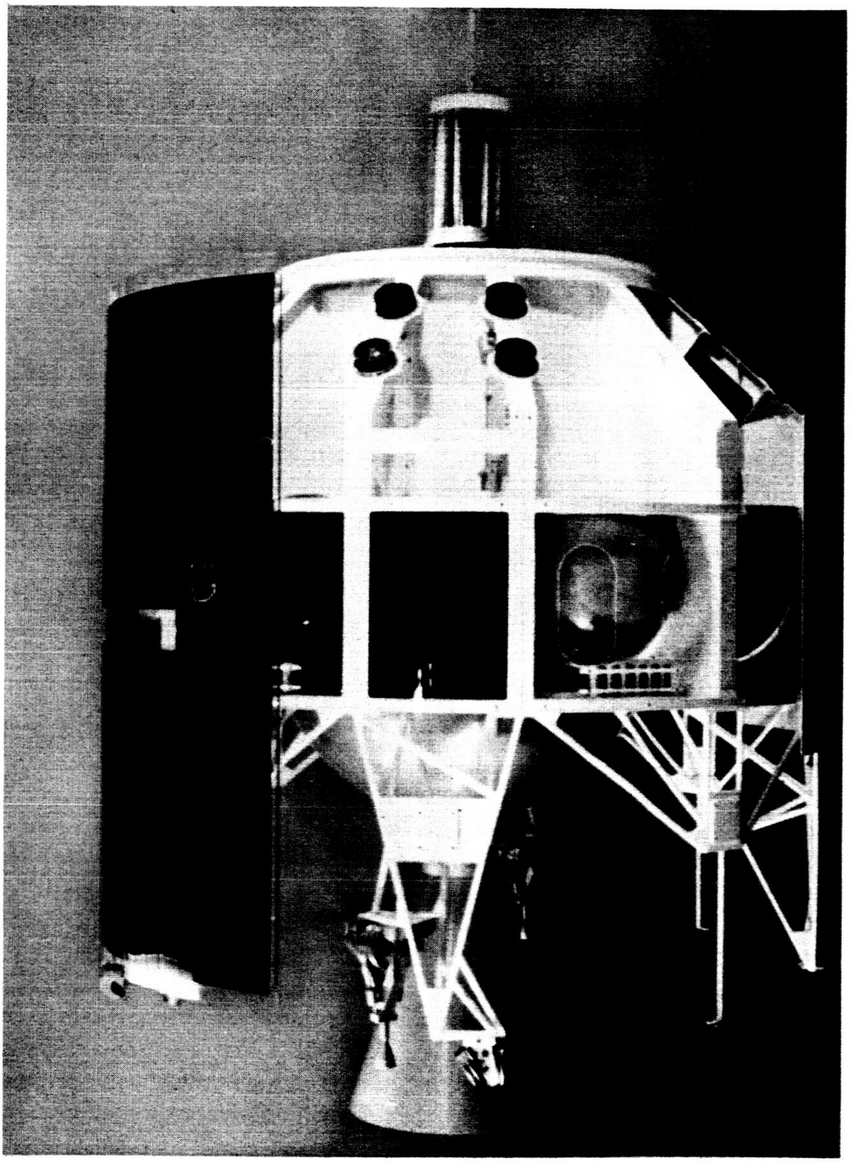


Figure 3–6. Advanced Technological Satellite.

Advanced Research and Technology

NASA's Office of Advanced Research and Technology is responsible for developing the underlying body of scientific and technological knowledge which supports the Nation's active airborne and space flight programs. The work of OART includes 2,000 separate tasks and projects in basic research, applied research, engineering research, and experimental development of advanced subsystems. This research has the following objectives:

- Basic research—an understanding of the natural laws underlying aeronautical and space technology.
- Engineering research—the application and codification of these natural laws in terms of engineering design principles.
- Experimental subsystem development—the use of advanced concepts and components for the design of future operational systems.

This research, which seeks to improve knowledge of aeronautical and space vehicle systems and subsystems and of their human operators, is essential to uninterrupted progress in space science and technology. It calls for the wide range of activities discussed in this chapter: investigations in space power technology, space vehicle systems, launch vehicle and spacecraft electronics and control, aircraft aerodynamics, biotechnology and human research, advanced nonnuclear propulsion systems, and basic research.

Space Power Technology

All spacecraft require electrical power. The research and technology effort which seeks to use chemical and solar energy to provide such power is the basis of NASA's space power technology program. (For nuclear power see ch. 5, p. 135.) Its work ranges from basic studies to the demonstration of new and improved devices and systems.

Solar Cells

Solar cells convert sunlight directly into electricity and are thus useful in space applications. However, they have the disadvantages of low resistance to radiation and relatively high weight per unit of power output. During this period, progress continued on the development of cells more resistant to radiation damage and on understanding the physics of the damage process. One example of this work is an experimental silicon solar cell prepared at Lewis Research Center. By eliminating trace impurities known to be involved in the damage process and by reversing the polarity of the exposed surface of the cell, the resistance of the cell to radiation was increased about 12 times over that of previously used cells.

In efforts to reduce the weight of the solar cell array, NASA instituted an in-house study of the thin film solar cell (Ch. 4, 9th Semiannual Report.) Since this approach involved new fabrication techniques, a pilot facility was established in industry to produce 6- by 6-inch cadmium sulfide thin film solar cells in sufficient quantities for testing. Tests included an evaluation of the simulated effects of the space environment on the new cells. Preliminary data indicated that they were quite resistant to radiation and offered the additional advantage of being sufficiently flexible to be rolled up for storage. This work is an essential preliminary to detailed studies of the systems problems involved in using such cells.

Thermionic Power Converters

Basic research studies of direct conversion of heat energy (as from the sun) to electricity by the thermionic process continued. New diagnostic tools and techniques developed under this program were employed to acquire information about the phenomena and the limitations. The effects of emitter surface preparation were studied by directly observing electron emission. In addition, studies on experimental diodes of the effects of various gas additives to the interelectrode space indicated that it may be possible to improve the efficiency and power density of these devices.

In the applied engineering phases, data was accumulated on fabrication techniques and related variables in laboratory and solar tests on experimental hardware, and efficiency and life were improved.

In related research, the first phase of a program to provide the technology for fabricating very accurate, lightweight paraboloidal mirrors to produce the necessary high temperatures for thermionic conversion was completed. A precise plastic master to assure the geometric contour of the mirror replica was produced by spin casting, and a sample 9.5-foot diameter mirror was being evaluated. Progress was also made in thermal property tests of high melt point materials. These were studied as thermal energy storage materials for use with solar thermionic systems.

Solar Dynamic Systems

Work continued on the Rankine cycle systems, using mercury as the working fluid, and on the Brayton cycle system using argon as the working fluid. Single solar dynamic systems of this type could provide 4.5 kw. to 8 kw. of useful electrical power, or be utilized in multiples of four or five for power levels up to about 40 kw. of electrical power.

Since the last report, notable progress was made in two major phases of the solar Rankine cycle system research. The turboalternator completed an endurance test totaling 4,328 hours in September, with no indication of performance degradation or bearing wear. On the basis of this test, it was concluded that one year operation of such equipment is a reasonable design goal. The second advance was in the search for a suitable hydrogen barrier material, to minimize hydrogen diffusion through the boiler wall. The ability of a high temperature glass coating to contain hydrogen was demonstrated through extended capsule type tests. Plans were formulated for the fabrication and test of a flight-type boiler to verify these materials test results.

Research efforts on the Brayton cycle systems were directed toward advancing the technology for the system components. Two design studies for the 30-foot diameter solar collector neared completion; one is based on a nickel-electroforming fabrication technique, and the other on an aluminum stretch-forming technique. Fabrication and subcomponent heat transfer tests of the receiver-heat storage unit were underway. Radial compressor-turbine machinery was being procured and will be evaluated in comparison with similar axial machinery; no contract for the latter has been awarded. Also, design and fabrication of the recuperator was started, and heat exchanger effectiveness was being investigated. As prototype components for the Brayton cycle power system become available, intensive performance and operational tests will be conducted at the Lewis Research Center.

In support of the solar dynamic and thermionic systems, research continued on advanced materials and fabrication techniques for large, efficient, high-temperature solar concentrators. The first phase of a study to define a flight experiment for determining the life and performance of highly reflective surfaces in the space environment was satisfactorily concluded. Data from such a flight experiment is basic to the development and application of space power systems, which use a solar concentrator for obtaining the requisite system operating temperature.

Batteries and Fuel Cells for Space Applications

During this period, a significant advance was made in the search for lighter weight, longer life batteries through the addition of a third electrode to conventional batteries. The third electrode is essentially a fuel-cell cathode which causes the oxygen, released during the electrochemical process, to recombine. A small electrode can be used to signal the onset of gassing, so that the battery can be taken off full charge and put on trickle charge; or a large third electrode can be used to recombine oxygen as fast as it is formed. In either case, the pressure in the cell can be kept low, making it possible to eliminate the heavy steel retaining plates and steel cases and to cut down on the amount of excess cadmium used to avoid hydrogen formation. Thus, battery weight can be substantially decreased. Also, the third electrode will permit dissipation of some of the heat outside the battery.

An additional advantage of the third electrode is that signals can be taken from it to indicate when a battery is fully charged. With this knowledge, overcharging or undercharging can be prevented thereby increasing battery life and reliability and giving more power per pound of battery in the system. Third electrode batteries were being life tested during the report period.

Under a NASA contract, a hybrid battery/fuel-cell concept was shown to be feasible. The device, applicable to any combination of electrochemically active materials, consists of a tape coated with anodic matter on one side and cathodic on the other and an encapsulated electrolyte. By releasing the electrolyte just before the tape moves through two current collectors, electric power is generated. The advantages are that the reactants can be stored indefinitely, highly active materials can be used, and high energy-to-weight ratios are possible. The first demonstrators used silver oxide coatings on one tape, concentrated caustic solution in another tape, and a consumable zinc electrode block. Work continued on a single tape with double coating and on an encapsulated electrolyte.

Progress was also made in applying a new passive heat removal concept to a regenerative hydrogen-oxygen fuel cell. Such a fuel cell is charged by electricity derived from solar cells when sunlight is available; during dark time, it supplies electricity. For cooling, a solid material is melted by the heat which the cell gives off; this material, in turn, is cooled by a radiator and then solidifies. This method replaces the system of pumping a liquid coolant through coils embedded in the cell. Passive heat removal eliminates the pump with its moving parts and thus should increase reliability.

Space Vehicle Systems

Environmental Effects

High Energy Radiation Effects and Shielding.—The effects of high energy electrons and protons on spacecraft materials and components were studied experimentally and analytically. Construction began on the Space Radiation Effects Laboratory (SREL) at Langley. SREL, expected to be completed in 1965, will contain a 600 million electron volt (Mev) proton accelerator and two electron accelerators. Also, a gamma probe was developed to calibrate the shielding effectiveness of thin wall space vehicles. Precise nuclear data were obtained on the transmission of high energy electrons, protons, and their secondary radiation products through spacecraft materials. Proton shielding experiments using a 160–Mev proton accelerator were completed, and plans were made for additional experiments at lower proton energies using another accelerator.

Meteoroid Environment and Impact Hazard.—The Explorer XVI satellite, launched December 1962, provided the first significant information on the penetration of thin metallic surfaces by meteoroids. These data and ground based meteor observations from a radio meteor project under NASA contract at Harvard indicated that previous estimates of the meteoroid hazard to spacecraft must be revised and that further data are needed to predict the hazard accurately. For this purpose, more Explorer XVI type satellites will be launched. In addition, a larger satellite will be launched by a Saturn booster during Apollo development

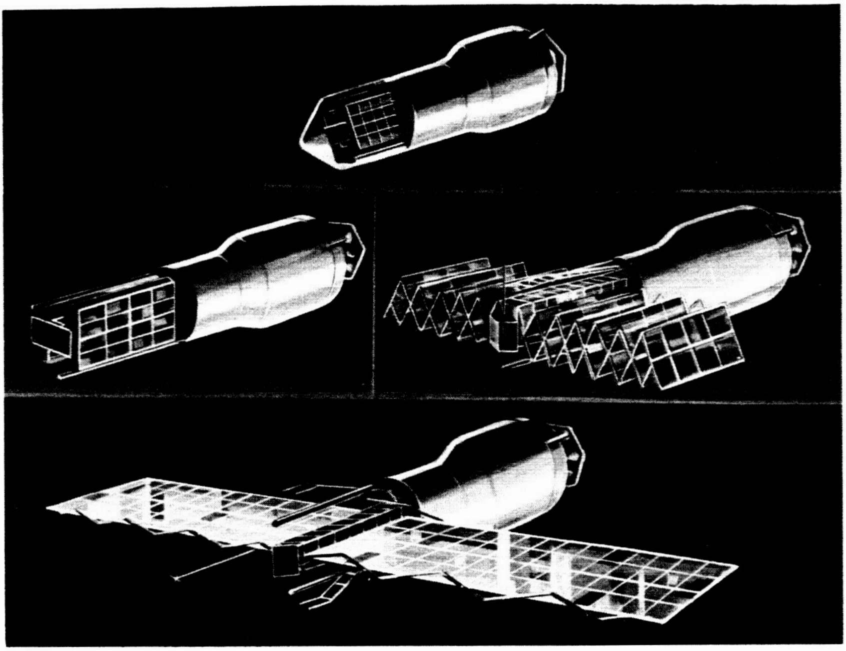


Figure 4–1. Saturn-launched meteoroid satellite unfolding sequence.

tests. Development was well along on two Saturn-launched meteoroid satellites, which will expose a meteoroid penetration sensing area about 100 times larger than that of Explorer XVI. Because of its large area, the satellite must be folded for its flight into space; then it unfolds (fig. 4–1) to expose a flat area of 2,000 square feet with a span of about 117 feet.

Other flight experiments to collect data on meteoroids were planned. These included a recoverable meteoroid probe to obtain direct measurements of the frequency of impact and penetration depth of small particles and an artificial meteor experiment to provide controlled data on the luminous efficiency and ionization accompanying simulated meteors of known mass, composition, material, size, and shape at meteoroid velocities. The results of these experiments, along with data from the ground based Harvard radio meteor project should make it possible to measure the mass of meteoroids seen entering the earth's atmosphere. (The Harvard project employed a technique of bouncing radio signals off the ionized trail particles produced when a meteoroid enters the atmosphere. From the reflected signals, speed, direction, and number of meteoroids in a given size range can be determined.)

Zero Gravity Fluid Behavior.—The initial series of drop tower and space probe rocket powered tests to study equilibrium configuration for liquids in tanks under zero gravity conditions was completed. The results indicated that specialized tank geometry can be useful in positioning fuels to permit their pumping and venting in a weightless state.

Thermal Radiation and Temperature Control.—Development work continued on two types of active devices for automatic control of spacecraft skin temperature: Mechanical and electronic. A mechanical device being studied under a NASA grant involves thermoactive metallic strips embedded in the spacecraft skin so as to protrude slightly. Theoretical calculations indicated the feasibility of the device, but it was not tested in the laboratory or on a spacecraft.

Two types of electronic spacecraft skin temperature control devices demonstrated feasibility in NASA laboratory tests. These devices are made of semiconducting materials which alter their radiative absorption and emissive characteristics with changes in temperature or applied voltage.

Studies showed that half scale models can be used for thermal testing of simplified spacecraft. Further experimental work based on these studies was planned. Such work could lead to a reduction in the size of facilities needed for future testing.

Aerothermodynamic and Related Problems

Launch Vehicle Heating.—Base or tail end heating problems are common to the large liquid fuel boosters such as the Saturn I and Saturn V because of the intense heat radiating from the burning kerosene and the convection or swirling of the hot gases from the exhausts of the propellant pumps. The "afterburning" of the exhausts and high convective heating rates from interaction of the flows in multinozzle powerplants can cause temperatures to soar.

Lacking theoretical studies of the problems of base heating, investigators began their research on models in laboratory facilities. However, the models were extremely complex, very cumbersome, and expensive. Consequently, a new short duration testing technique was developed based on shock tube concepts. This new procedure reduced the cost per test from $750,000 to $35,000, and at the same time produced more complete data on base heating. It is also a more flexible research method.

Advanced Concepts

Lifting Reentry.—NASA's continuing research on advanced spacecraft moved forward as the Flight Research Center, Edwards, Calif., in cooperation with the Ames and Langley Research Centers, completed the initial phase of a lifting body flight program with the M–2 (described in the Ninth Semiannual Report, Ch. 4). The purpose of this research program is to investigate a class of spacecraft with operational flexibility and maneuverability within the atmosphere and a capability for a controlled landing on prepared runways; a further purpose is to investigate its flying and handling qualities at high landing and approach speeds. (Fig. 4–2.)

The first phase of this flight program was completed. In conjunction with extensive laboratory research, it proved that lifting body vehicles can be safely flown and landed. A 20-foot lightweight plywood glider, which is towed to altitude by an aircraft, made fifteen flights; its handling characteristics were reported to be similar in many ways to those of current fighter aircraft. In

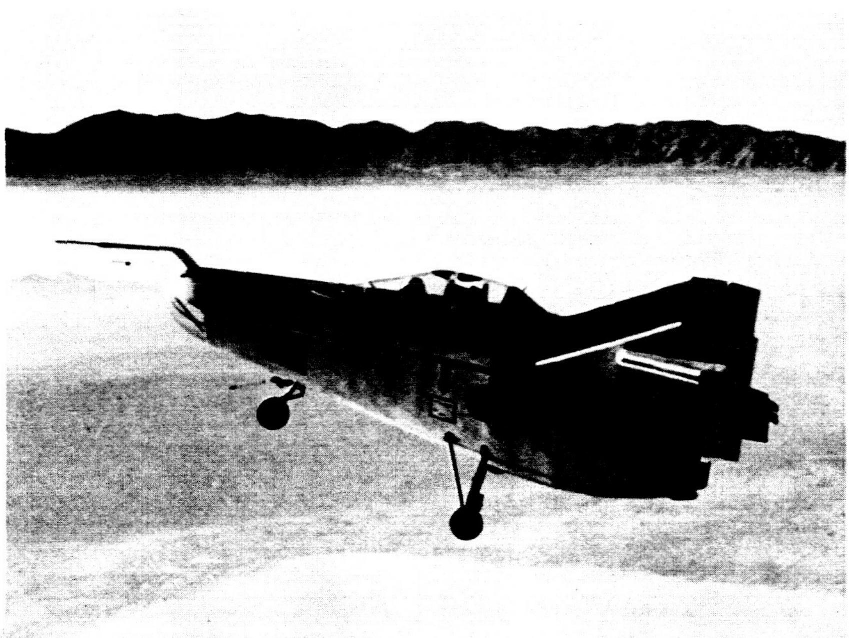


Figure 4–2. Lifting body vehicle in flight.

addition, information on lift-drag ratio, pilot visibility, stability and control, and landing approach techniques was obtained. As the period ended, research on heavier lifting body vehicles was being considered. Such vehicles would have higher wing loadings, representative of mission type vehicles, and faster landing speeds.

Spacecraft Landing and Recovery.—NASA continued studies of ways to improve the atmospheric landing and recovery capabilities of existing spacecraft. At the Ames Research Center, analytical studies were made to help define the potential uses of an Apollo-type spacecraft equipped with a rotor landing system. They showed that it may be possible to achieve spacecraft with gross weights no greater than current ballistic type spacecraft but with greater flexibility and range and the ability to land at zero impact velocity. On the basis of these studies, it will be possible to define the areas where experimental efforts can be most effectively utilized.

Electronics and Control

Communications and Tracking.—Studies indicated that a major improvement in deep space communications could be achieved by utilizing the optical and submillimeter portion of the frequency spectrum. Research was initiated to obtain basic data on the effects of the atmosphere on the transmission of laser signals and to devise means of minimizing adverse effects. Also, more sophisticated modulation techniques were investigated as a means of improving the overall efficiency of optical techniques.

Research in microelectronics included investigations of devices relatively insensitive to space radiation, of optimum packaging techniques, of methods of reducing the number of interconnections, and of improving reliability by understanding the mechanical causes of failure.

In the field of speech and data compression, research was initiated to reduce the length the time required to transfer information to and from a manned spacecraft; results were promising.

Langley Research Center began investigating ways of improving the data acquisition capability of ground antennas. (This capability is directly related to the size of the antenna or aperture—the larger the aperture the greater the capability.) It was found that individual apertures could be arrayed so that the threshold of detection of the array would be lower than that of the individual antennas. Studies were undertaken to determine the type of experimental facility needed to fully evaluate the technique and the effects of the atmosphere on the signal combining procedure.

Pilot Control During Boost Phase.—Studies were made of pilot control of large flexible launch vehicles during first-stage boost. The purpose of the research was to investigate simpler, more reliable control and guidance schemes which could utilize the adaptive control characteristics of human pilots. It also sought to determine to what extent the pilot should participate in the system as a manual backup for primary controller and to avoid disorientation on taking over in an abort.

For this study, a Saturn S–5 flight was simulated. The results indicated that a piloted control system can complete the control tasks during first stage of S–5 boost, that flexible structure motions sensed by the pilot do not present problems as false motion cues, and that such a configuration would be simpler and more reliable than an automatic system. Consequently, on Saturn 5 missions having a pilot and his instruments aboard for later use, piloted control is to be considered. Plans were made to extend this work to other boost mission phases and recoverable boost vehicles.

Guidance Sensor Research.—During this period, research on the technology of electrically suspended gyros for space use advanced significantly. A second phase experimental gyro was fabricated and the basic feasibility of the principle of electric suspension was established. The electrically suspended gyro has several advantages over the mechanically supported gyros: No mechanical contact to cause wear and decrease lifetime and accuracy, a truly "free rotor" gyro for flexibility of operation when affixed directly to the vehicle, and, thus, no need for heavy, precision gimbals and associated precision servos.

Under the direction of Marshall Space Flight Center, the Jet Propulsion Laboratory continued research on superconductive (cryogenic) gyros (Fig. 4–3) with encouraging results. Improved materials and techniques for fabricating such devices led to the initiation of performance tests on a cryogenic gyro. The test results (random drift rates in the order of 0.05° per hour) indicated a potential for further development.

Instrumentation.—During the period under review, a number of instruments and instrumentation techniques were developed or improved. For example, a rugged, wide range pressure trans-

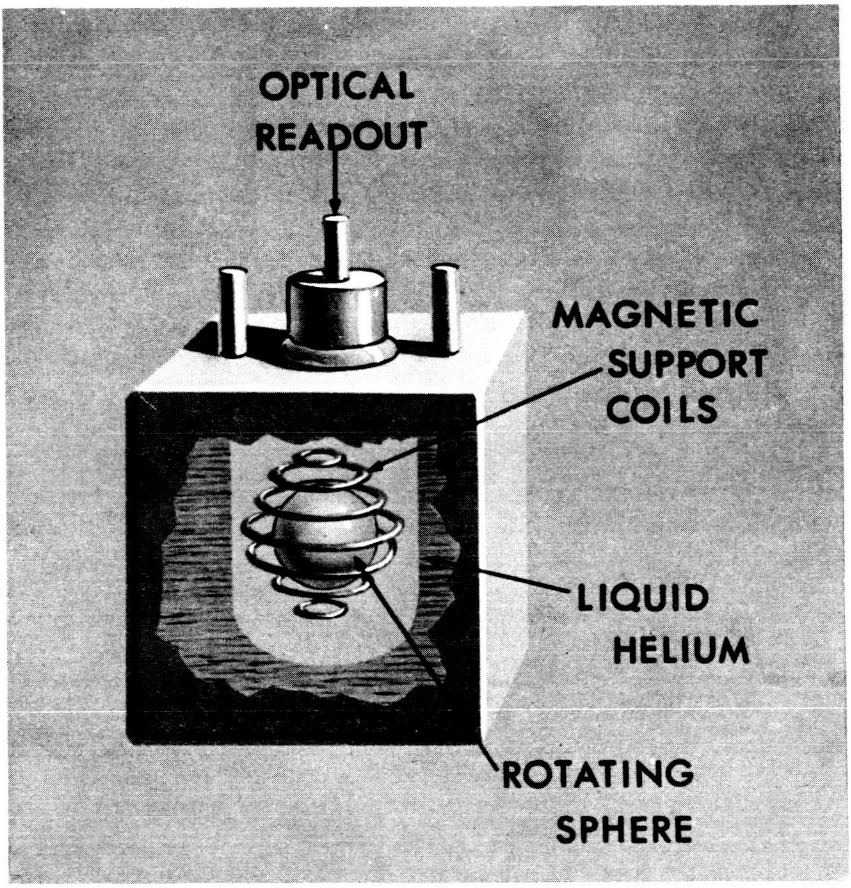


Figure 4–3. A cryogenic gyro.

ducer was developed at Ames Research Center. It can measure pressures from less than 1/100,000,000th of an atmosphere to a third of an atmosphere with an accuracy of 1 percent. The device (fig. 4–4), which responds rapidly even at low pressures, senses pressure through the damping effect of the gas being measured on a vibrating diaphragm. Vibrating diaphragms were also used to measure very small electric currents. They functioned with higher efficiency (greater output for a given electrical input) than any of the electrometers in general use.

Another example of such instruments is a pressure transducer yielding directly a digitized (pulse) output. A prototype was as-

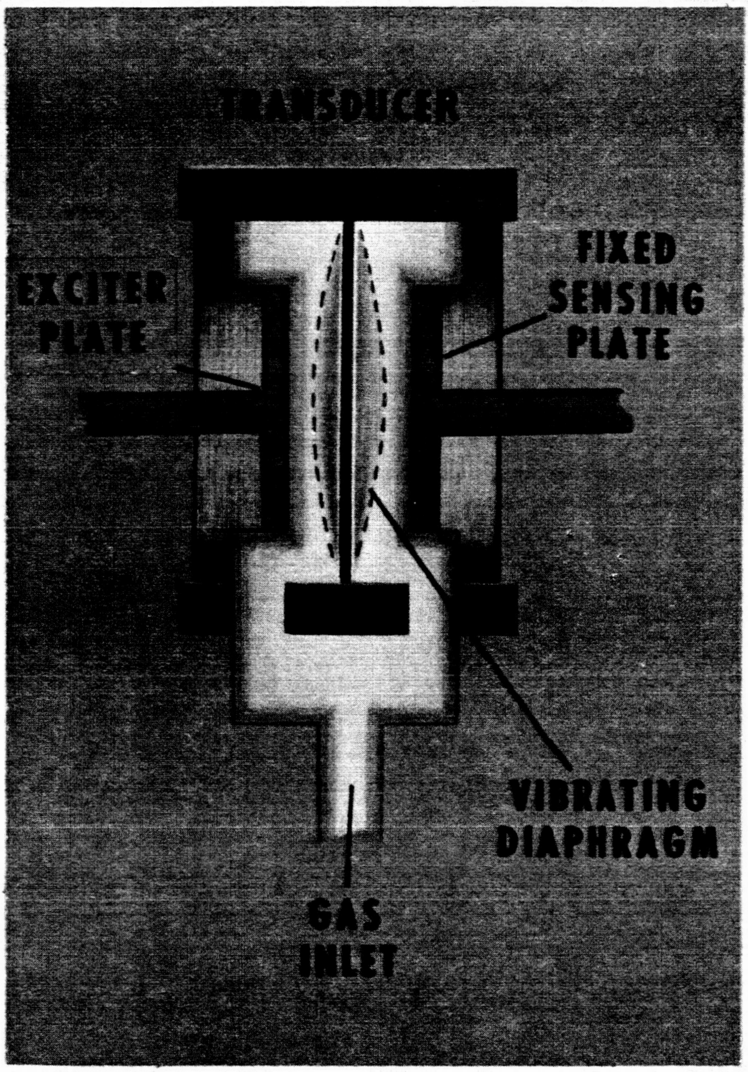


Figure 4–4. Vibrating diaphragm pressure measuring system.

sembled, stability problems were overcome, and the prototype was being evaluated.

Further, a miniature cryogenic liquids density sensor having an accuracy of 0.1 percent was developed by Marshall Space Flight Center. The device, which occupies a volume of only 1 cubic centimeter, can perform measurements in liquid oxygen and liquid hydrogen. At the Lewis Research Center, a more accurate method of calibrating liquid hydrogen flowmeters was found, and a piston vacuum gage was developed which measures low pressures with an accuracy of one millionth of an atmosphere.

Data Processing.—In this area, progress continued with work on a number of projects. Goddard Space Flight Center initiated development of a control and command system linking spacecraft and their test stations to permit automatic sequencing of spacecraft checkout tests and calibrations of scientific experiments. The system, which will first be applied to the OGO satellite, will enable an experimenter to rapidly select relevant samples of data, make decisions, and command further machine processing on a real-time, on-line basis. It will markedly accelerate the testing and calibration of spacecraft systems, substantially increase their reliability, and reduce costs.

A significant study was completed of a new type of computer system. Called an automatic pattern recognizer, it has groups of logical units somewhat comparable to living neurons, and can be trained under certain conditions to recognize patterns. A system of this kind might be "trained" to recognize cloud patterns for automatic weather monitoring and prediction systems, as well as for other applications.

A study of the state-of-the-art of fluid logical or amplifying devices was completed and was followed by further studies of space applications for such devices. These devices merit consideration because they permit high stepups in power and are highly reliable even in very hostile high radiation and temperature space environments.

Finally, digital system self-repair techniques were studied. Results indicated that there were ways of minimizing the number of spare parts required for systems that would last many years.

Aeronautical Research

Aircraft Aerodynamics

Research in this field advanced as analytical methods for prediction and optimazation of airplane drag at supersonic cruise speeds were refined and verified by experimentation. This work is expected to lead to significant reductions in wave drag, drag due to lift, skin friction, and adverse interference effects. Investigation of supersonic aircraft configurations continued. The effectiveness of the more sophisticated types of highlift systems for both variable sweep and fixed wings was further established. The data for minimizing longitudinal stability variations relating to Mach number and angle of attack were provided. And the lateral directional control problems of such configurations were investigated.

Aircraft Structures

Research on structural fatigue continued to be emphasized. A program was in progress to evaluate the fatigue and crack propagation characteristics of materials, such as titanium alloys, which were exposed to extended heating such as would be encountered in service. In related studies, structural specimens, such as box beams, were tested to ascertain crack propagation rates in typical structures.

At hypersonic speeds, refractory metals such as columbium and tungsten appear to be the most practical structural materials. Research was underway to develop structural designs and methods of fabrication for using these inherently heavy materials to build a light structure which would also be temperature-resistant (capable of withstanding a wide range of temperatures). A contract was awarded for the construction of a representative structural fuselage section of a hypersonic airplane, and plans were made for intensive inhouse testing of this section under realistic temperature and load conditions.

Air-Breathing Propulsion

Supporting research for the supersonic transport was continued and extended to include exploratory analyses of advanced propulsion systems for follow-on transport vehicles. A detailed investiga-

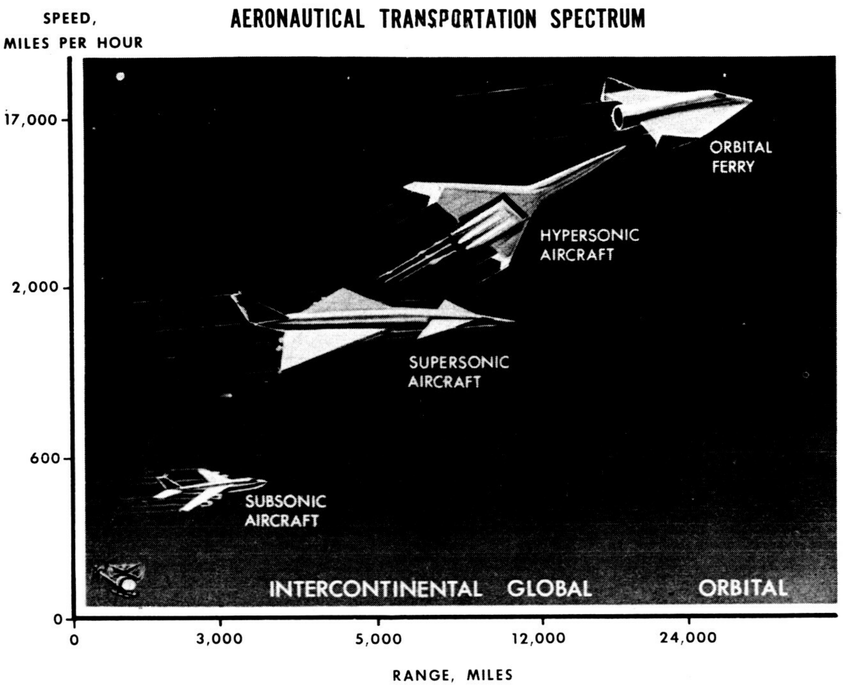


Figure 4–5.

tion of two sophisticated inlet systems resulted in considerable design information having direct applicability to the SST.

A study was conducted to determine the feasibility of using the X–15 airplane to obtain research information on advanced hypersonic air-breathing propulsion systems in a true flight environment. The results indicated that a ramjet engine such as the Typhon or an advanced hypersonic engine could be installed on the X–15, and that propulsion research could be carried on under flight conditions presently unobtainable in ground test facilities.

Operating Problems

Studies at the Langley Research Center on the phenomenon of pneumatic tire hydroplaning produced results of significance in flight safety research. Tire hydroplaning refers to the buildup of hydrodynamic pressures between the footprint of a tire and a paved surface that is flooded or heavily puddled with water or slush. In NASA's research it was found that as the speed of the aircraft or vehicle increases, a critical point is reached at which the hydrodynamic lift balances the weight riding on the tire. Additional ground speed results in lifting the tire footprint off the pavement; as a result the moving vehicle is in contact with the fluid alone. This condition, called total tire hydroplaning, results in loss of directional stability and braking effectiveness. The information now available can be used to establish safety criteria and procedures.

The results of these studies were published in a NASA Technical Note (TN D–2056) "The Phenomena of Pneumatic Tire Hydroplaning" and presented in a motion picture "Hazards of Tire Hydroplaning to Aircraft Operations." The film was distributed to a variety of interested groups, including aircraft manufacturers, airlines, Government agencies, and to automotive and safety groups. (The tire hydroplaning studies also apply to automobiles. Tire hydroplaning was found to occur in as little as 0.1 inch of water. When it occurs, friction forces between the tire and ground go to zero and brakes become completely ineffective. It was found that the speed at which hydroplaning happens can be expressed as a function of tire pressure. Fig. 4–6 illustrates this relationship.)

X–15 Research Airplane Program

The X–15 Research Airplane Program, conducted in cooperation with the Department of Defense, continued to provide data on manned, maneuverable hypersonic flight during the last half of 1963. Essentially all of the original program goals have been achieved. During the course of the entire flight test program, more than 50 flights have been made at speeds greater than Mach 4, including 41 flights faster than Mach 5. Three flights reached altitudes above 300,000 feet and another 9 above 200,000 feet.

Early in 1963 the decision was made to repair the X–15A–2 airplane (which had been damaged during an emergency landing on November 9, 1962), and modify it to increase its performance capability. The modification will provide a design mission of Mach 8 at an altitude of 100,000 feet. Modifications include two external

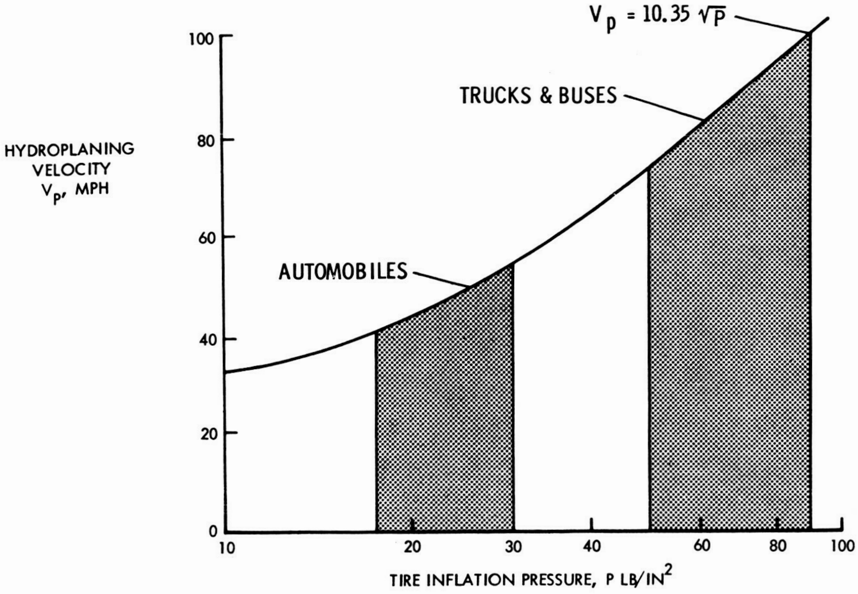


Figure 4–6. Chart shows relationship between tire pressure, velocity, and hydroplaning.

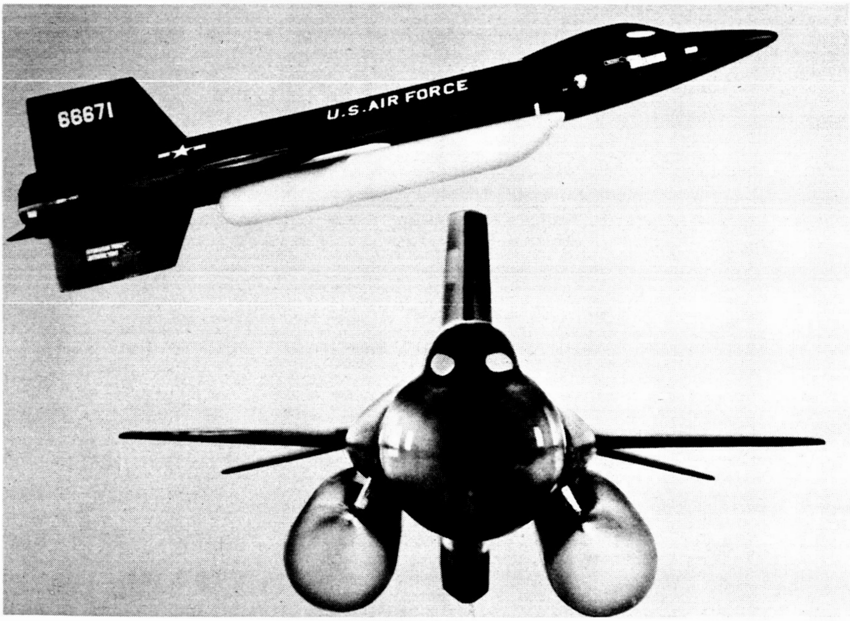


Figure 4–7. Modified X-15A-2 showing external pressure tanks.

propellant tanks (fig. 4–7) to give larger engine burning time, and improved windshield configuration, landing gear, and research instrumentation. Work on the airplane went forward, and the first flight of the modified airplane was tentatively set for the summer of 1964.

As the X–15 program has progressed, new problems have been defined in structures, stability, control, heating, and operations which will require additional research. The X–15 Joint Program Coordinating Committee recommended to the Research Airplane Committee that the aircraft be used to obtain additional vitally needed research data, especially in air-breathing propulsion, aerodynamics, and structures. This recommendation was based on the fact that the X–15 is the only vehicle available to get this information. With the additional flights required to obtain the data, the bulk of the program would end in 1967. One airplane—the X–15 with the Mach 8 modification—would continue in flight-test to the end of 1968.

The X–15 program has contributed to the knowledge and increased the confidence of designers of current high-performance aircraft and in doing so has also focused attention on the areas which require additional research—hypersonic air breathing propulsion systems, structural concepts, and infrared high-temperature materials. The future program will be directed toward these areas and will provide information for the next logical step in our flight research program—manned, maneuverable hypersonic flight.

Supersonic Transport

Since 1956, NASA and its predecessor agency, the NACA, have conducted research to provide the technology for a supersonic commercial air transport (SCAT). Various aircraft configurations embodying widely differing design features—all promising in performance and aerodynamics—resulted from this research. Contracts were let early in 1963 to two major airplane companies for detailed, comprehensive engineering design studies of four of the promising configurations—an arrow wing, a delta wing, and two variable sweep configurations (fig. 4–8). In September 1963, a technical conference was held at the NASA Langley Research Center at which the results of the industry design studies and of NASA inhouse research programs were presented to representatives of the Federal Aviation Agency, of other government agencies, and of the major aircraft manufacturers.

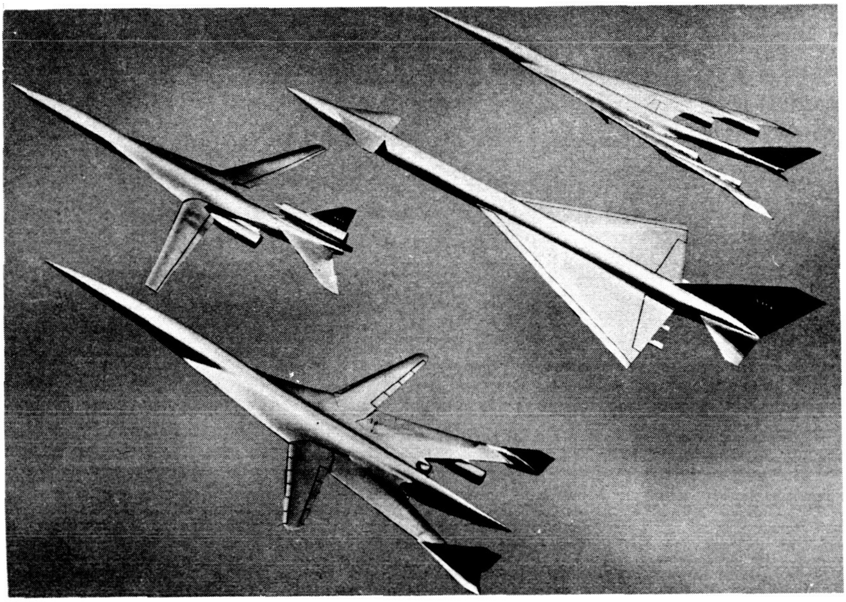


Figure 4–8. Four promising SCAT configuration concepts.

The conference showed that a safe, reliable supersonic transport is technically feasible, but that additional research is required to obtain the desired economy of operation.

Other points brought out during the conference were the following: A dominant design factor will be a requirement that sonic boom intensity not exceed certain arbitrary values; titanium alloys hold forth the promise of an efficient light weight structure capable of withstanding the temperature of Mach 3 flight; and new and advanced engines will be required.

NASA is conducting research on all these problem areas. For example, in investigations of the sonic boom it was found that the intensity of sonic booms can be estimated theoretically and that it is possible to estimate boom overpressures on the ground for given flight conditions with considerable accuracy. However, two problems remain which require further research—defining realistic limits of public acceptance of booms, and investigating the effects of atmospheric conditions on the intensity of sonic booms heard on the ground.

Vertical and Short Takeoff and Landing (V/STOL) Aircraft

Research continued on a variety of flight, wind-tunnel, and simulation V/STOL projects. Three important studies were completed in late 1963. They were concerned with the effects of wind tunnel walls on tests of fan-in-wing aircraft, with lateral control power requirements of V/STOL aircraft going from hover through transition flight; and with operational problems caused by ground impingement of downwash from VTOL aircraft.

The reliability of wind-tunnel data obtained on V/STOL models which are large in relation to the tunnel throat has been a matter of concern for some time. Therefore, an investigation was made of the effects of tunnel walls on the aerodynamic characteristics of a fan-in-wing V/STOL configuration in the transition speed range. Repeat tests were run of one model in three different size tunnels using a dynamically scaled free-flight model of the GE–Ryan XV5A fan-in-wing airplane. Research was conducted in the 17-foot and 7- by 10-foot test sections of the Langley 300-mph 7-

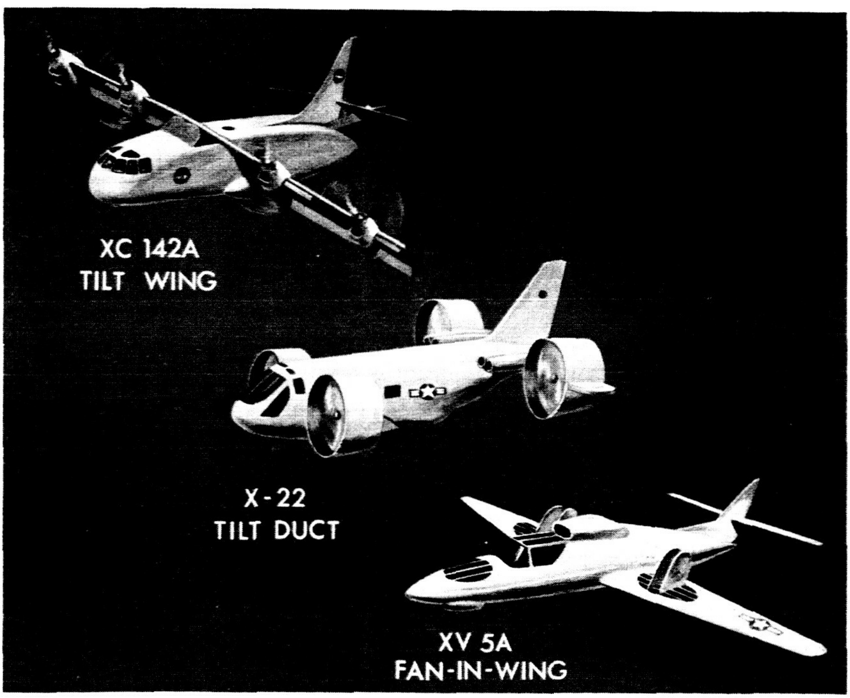


Figure 4–9. Prototype V/STOL aircraft.

by 10-foot tunnel and the Langley 30- by 60-foot tunnel. In the 7- by 10-foot test section, the model-size to tunnel-size ratio was slightly larger than that of the full-scale XV5A airplane in the Ames 40- by 80-foot tunnel. Only very small differences were obtained in the drag and pitching moment results in the three tunnels. However, the lift data indicated a significant wall effect: The lift appeared to be appreciably greater when measured in the 7- by 10-foot test section than when measured in the interference-free 30- by 60-foot test section.

The second of this group of studies sought to determine whether any significant changes could be expected in the lateral control power requirements of V/STOL aircraft as they proceeded from hover through transition flight and whether cross-coupling parameters affected the pilot's rating of the lateral characteristics of STOL aircraft during the landing approach. This research, part of the Ames general research flight program, used the X–14A variable-stability VTOL airplane flown at approximately 40 knots.

In general, the study indicated that during transition, less total lateral control power will be required than will be needed during hover. Preliminary results also indicated that lateral-directional cross coupling exerted considerable influence during simulated STOL approaches. In addition, it was found that the pilot's rating of the lateral flying characteristics improved substantially when a change was made from adverse yaw to favorable yaw characteristics during approaches with aileron control power held constant.

The final study of this group sought solutions to operational problems arising from ground impingement of the downwash from the engine exhausts of VTOL aircraft. The requirement for a high-performance VTOL aircraft having high exhaust pressure jet engines conflicts with the requirement for low ground impingement pressures. Consequently, NASA contracted for an experimental study of exhaust nozzle design factors to alleviate the ground impingement problem by increasing the rate at which the exhaust mixes with the surrounding air. Twelve nozzle configurations were tested, and it was found that three basic nozzle design factors were very effective in causing rapid pressure decay in the jet wake and thereby reducing ground impingement with only a small loss of engine thrust or lift efficiency.

Hypersonic Aircraft

Hypersonic aircraft are of interest because they offer the possibility of achieving a high speed, long range earth-to-earth transport system linking cities 5,000 or more miles apart in 1 hour to 1½ hours of travel time. The hypersonic aircraft could also serve as the reusable first stage of an earth-to-orbit transportation vehicle.

During the period, experiments and theoretical analyses were conducted on the propulsive, aerodynamic, and structural efficiencies of potential hypersonic-cruise aircraft for global and orbital transportation. Direct supporting research included investigations of hypersonic inlets, supersonic combustion ramjets, structural concepts for containing hydrogen fuel in a sustained hypersonic (hot) environment, and aerodynamic components for winged air-breathing systems. Some experimental data at hypersonic Mach numbers was obtained for delta wings, half-cone-delta-wing combinations, and research configurations with air inlets and stabilizing surfaces.

Biotechnology and Human Research

The Human Factors Systems program carried on a wide range of activities, including the development of interagency coordination procedures, research on human functions in relation to aerospace environments, investigations of life support and protective systems, and studies of man-system integration.

The Life Sciences Subpanel of the Aeronautics and Astronautics Coordinating Board is the medium for interagency review and coordination in the life sciences program. The Subpanel is composed of a NASA chairman, a DOD vice chairman, and members from Army, Navy, Air Force, and NASA program offices. During the reporting period, the Subpanel developed the Interagency Life Sciences Supporting Space Research and Technology Exchange (ILSE). ILSE is a coordination, planning, and management tool to identify and coordinate DOD and NASA life science research efforts for the efficient use of manpower and funding resources.

In fulfilling its purpose, ILSE keeps DOD and NASA life sciences organizations aware of current support research and technology, identifies and eliminates unnecessary duplication of effort, and helps identify important areas where little or no effort is being applied by either agency.

Human research effort continued with stress on investigations of man's functions in aeronautic and space environments. In research on normal and altered vestibular functions, the sensing hair cells which detect fluid motion in the canals of the vestibular labyrinth were identified as the source of the sensation giving rise to motion sickness. Also, computing techniques were developed to detect changing patterns of electrical brain waves as states of consciousness shift from full alertness to deep sleep and pathological unconsciousness. These techniques may have future use in predicting the effects of extended space flight on the human systems. Finally, in research on the biological effects of magnetic fields, measurements were made of the blood chemistry of mice living in a magnetic field of 7,000 gauss for 2 weeks. During this time, the mice showed a 29-percent decrease in white blood cells and a 21-percent increase in red blood cells. The importance of these findings rests in the fact that the magnetic field used was only about 1/50th of the strength required for shielding a space vehicle from ionizing radiation.

In the area of life support and protective systems research, several projects moved forward. In an integrated multiman equipment test, the atmosphere of a simulated space vehicle was regenerated by a sodium superoxide system which removed the carbon dioxide and supplied oxygen to support life. This study also tested a closed waste disposal system in which the urine and feces were treated in a biological reactor employing the activated sludge process to produce potable water for reuse by the crew. In addition toxicological, microbiological, behavioral, and food problems were included in the study.

An advanced breadboard model of an electrolytic oxygen generation unit was in operation at the Ames Research Center. This unit can generate breathing oxygen from water vapor in the atmosphere of a closed-space cabin.

An integrated biomedical sensing and recording system was being developed under contract for use at the Flight Research Center. This is the first phase of a program to evolve a closed loop psychophysiological sensing, computing, and control system. Design of the various sensors, signal conditioners, telemetry systems, and recorders which make up the system was completed or in process during this period and most of these items were being fabricated. Plans were made for X–15 and F–104 flight tests of segments of the system.

In man-system integration studies conducted at the Ames Research Center it was found that a pilot loses control of the vehicle when there is a completely unexpected failure of the stability augmentor system. However, if failure of the augmentor system is expected, even though time of failure is unknown, the pilot is able to maintain vehicle control.

An investigation was conducted on the Ames 5°-of-freedom simulator to determine how the ability of a pilot to perform meaningful tasks is affected when he is subjected to low frequency, high amplitude vibrations, such as will be experienced in the launch phase of Apollo. Results indicated that pilot performance does not start dropping off rapidly until the oscillatory acceleration reaches 1½ to 2 g's.

Chemical Propulsion Systems

Solid Propulsion Systems

Solid propellant motors are widely used in the Nation's space systems and are expected to be applied even more extensively. Applications include use in sounding rockets, Scout launch vehicles, Little Joe test vehicles, Ranger and Surveyor retrorockets, Syncom I and Advanced Syncom apogee motors, as well as in 25 of the 89 thrustors of the Apollo system. The advantages offered by solid propellant motors are reliability, storability, ease of manufacture and launch, short development time, and more impulse in a smaller package. During the period, NASA continued efforts to improve the technology, extend the capability, and increase technical understanding of solid propellant systems. Investigations were primarily concerned with combustion instability, stop-restart solids, and small impulse systems for space vehicle control.

Combustion Oscillation Research.—Work in this area was conducted at the Naval Ordinance Test Station. A tubular device was developed to simulate the acoustical resonance phenomena which appear in large solid motors. Data on oscillations collected by burning a propellant in these 6-inch tubes correlated with known motor instabilities. This apparatus, requiring only pounds, rather than millions of pounds of propellants, will be used to test the propellants for the 260-inch solid motors.

Spacecraft Motor Technology.—In this area, work continued on stop-restart solids, and small impulse multiple pulse systems for space vehicle control. Research on stop-restart cycles in solid propellant motors was carried on at NASA's Lewis Research Center and the Jet Propulsion Laboratory. Two of the several techniques investigated seemed most promising; further study of these methods of effecting multiple starts was planned.

Research on small multiple pulse solid systems for use in long-lived satellites, carried on at Goddard Space Flight Center, indicated that such systems are needed for spacecraft control in certain missions. One such unit, the "cap pistol," a series of single, tape mounted, subminiature solid propellant rocket motors producing 0.01 lb./sec. total impulse each, was being prepared for flight testing on the TIROS satellite in 1964. The motors can be fired at a maximum rate of 20 per second with each successive unit moved into place by a small motor. (Fig. 4–10.)

The subliming solid control rocket (fig. 4–11)—another multiple pulse attitude control system—was being developed under contract. This rocket produces thrust by exhausting a low-molecular-weight vapor through a nozzle. The vapor is obtained by sublimation of a solid at ambient temperature, without ignition, combustion, or high temperature. The propellant is stored as a solid at low pressure with a consequent low systems weight. The system offers potential high reliability because of its low operating pressure and simplicity, and a specific impulse of 85 seconds compared with 75 seconds for a cold nitrogen system.

Studies were also made of a more highly simplified valveless subliming system based on a radiant energy source and a sublim-

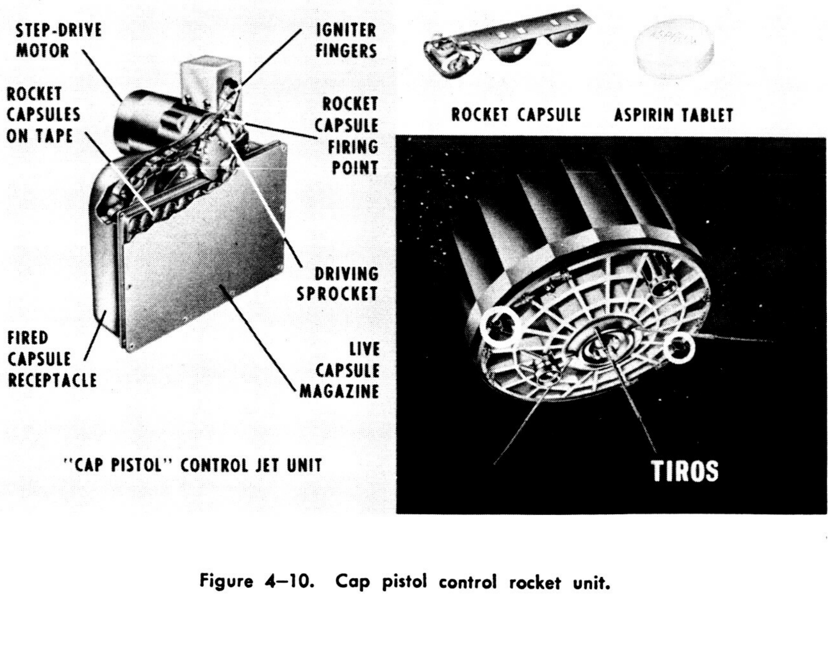


Figure 4–10. Cap pistol control rocket unit.

ing material. Heat from the radiant energy source vaporizes the material to produce thrust; sublimation and thrust cease as soon as the energy source is turned off. In tests, the method appeared to be practical up to 0.1 lb. of thrust and feasible for small impulse-multiple pulse systems.

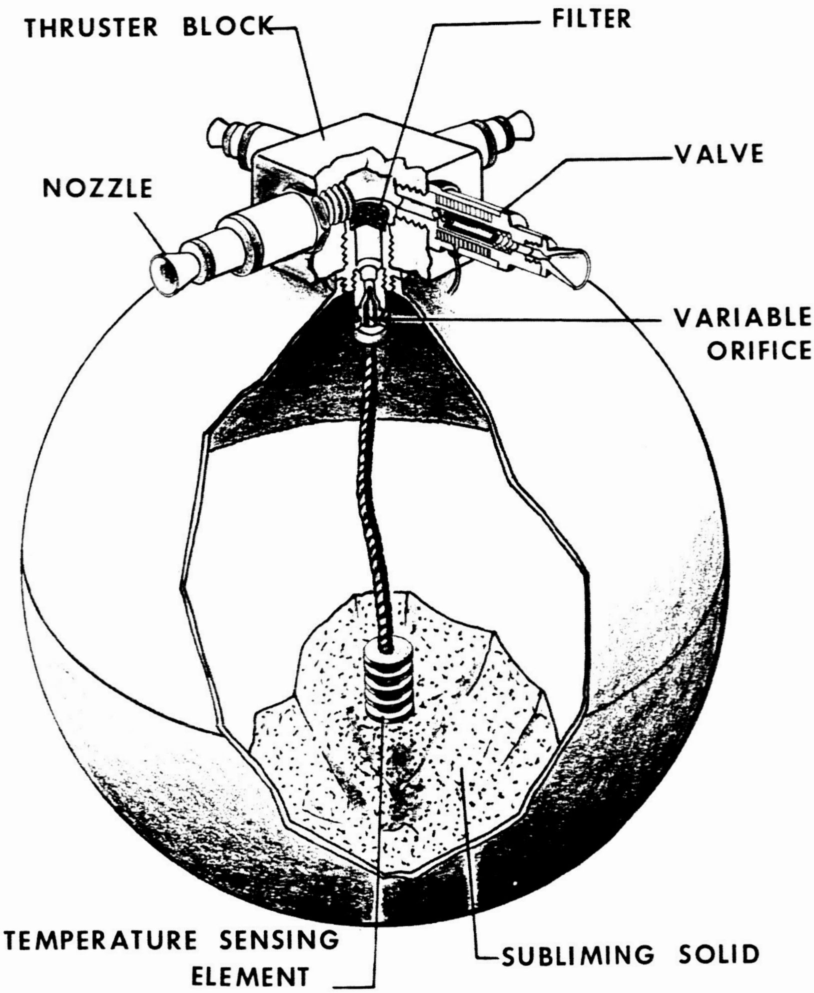


Figure 4–11. Subliming solid control rocket.

Liquid Propulsion Systems

Work in this area embraced investigations of engines for future launch vehicles, of propulsion technology, and of propellant storability and sloshing.

Advanced Launch Vehicle Engines.—During the period, work on the multichamber concept, which can be adapted to the needs of a variety of vehicles by using many of the same engine components, demonstrated its feasibility. This research also yielded engineering data on the effects of the interaction of multiple supersonic streams in a common nozzle and information from hot firing tests on critical heat transfer effects.

Full scale tests of the toroid combustion chamber were under way. A four tube segment at chamber pressures of 2,000–2,200 psia with hydrogen/oxygen produced thrusts of 70,000–80,000 pounds without a nozzle. With a nozzle, this would be about 100,000 pounds at sea level, increasing to 120,000 pounds at 70,000 feet.

Studies were also being conducted on the aerodynamic nozzle (fig. 4–12). In this concept, high pressure gases from the engine interact with a very low rate secondary gas core to form an interface resembling a mechanical plug nozzle contour. The thrust is obtained from the pressure of the secondary gas acting over the base. The aerodynamic nozzle makes a minimum length engine possible because no mechanical nozzle structure is required and because a minimum of thrust structure is required to transmit the thrust forces to the vehicle.

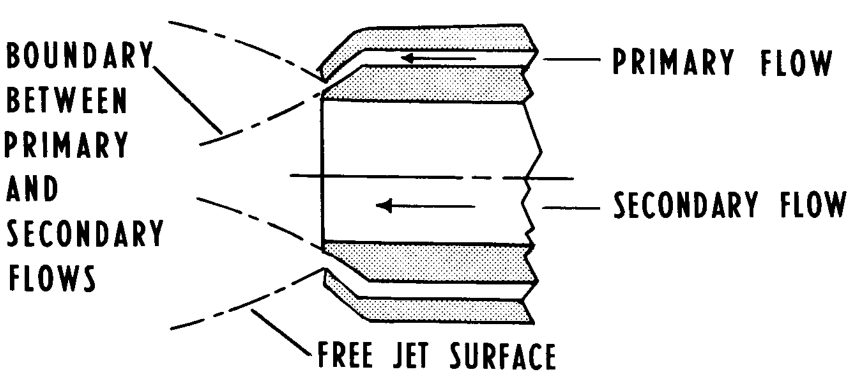


Figure 4–12. Schematic diagram of the aerodynamic nozzle.

Spacecraft Propulsion.—In this area of investigation, efforts were directed toward improving the design of the metallic bellows to increase its reliability. Such a device is needed to achieve positive flow of propellants to give a spacecraft engine a restart capability under zero gravity conditions.

Work also continued on pyrolytic graphite materials for thrust chambers. Free standing chambers for thrusts up to 2,000 pounds were produced, firing tests were conducted, and research on temperature and stress distribution was underway. Using these materials, it may be possible to produce thrust chambers weighing up to 50 percent less than those made of other substances frequently used for this purpose.

And, in research on refractory metals for thrust chambers, high temperature protective coatings were prepared capable of withstanding temperatures of 4,200° F.

Propellants.—A project was initiated to investigate storability of the diborane/oxygen difluoride propellant combination. Experimental data indicated combustion efficiencies at 2,000 pounds thrust near the theoretically predicted values. Plans were made to continue work on combustion characteristics, on performance at high-altitude operating conditions, and on appropriate chamber designs.

Another problem under investigation was sloshing—the movement of propellants in tanks. Sloshing is a serious problem because it can affect the structure and control of the vehicle. This is particularly true where hydrogen is the propellant because of the large tanks required. One solution to this problem is gelling of the propellant. The gel is a cohesive mass that still possesses the physical properties of a liquid when the appropriate forces are applied. During the period, investigators succeeded in gelling liquid hydrogen.

A hydrazine catalyst for advanced monopropellant systems was developed and the material was accepted for use. A proposal that this development be used as the propulsion system for an astronaut spacebelt was under consideration.

Basic Research

Fluid Physics

The fluid physics program seeks to provide information on and understanding of the flow processes of liquid and gas mixtures involved in aircraft, spacecraft, and advanced propulsion systems. Knowledge of a fluid physical property such as thermal conductivity is an important factor in choosing the type and weight of the heat protection system for a vehicle; a property such as viscosity of the air relates to drag and influences the shape of an entry body. NASA research included work on plasma oscillations and fluid properties.

Plasma Oscillations.—Oscillations occurring in a plasma and their effect on stability and control of plasmas in such devices as plasma accelerators and energy converters were investigated and qualitative and quantitative agreement of theory and experiment were achieved. At the Langley Research Center, the onset of oscillations in a magnetoplasma was investigated for a linear Hall-current plasma accelerator. This investigation determined the dependence of the oscillations and their transition to turbulence upon various controllable factors.

Fluid Properties.—A new method of measuring the transport properties of a gas under entry conditions—ordinarily extremely difficult because of the high temperatures involved (up to 40,000° F.)—was developed under NASA contract. This method measures the attenuation of ultra high frequency sound waves passing through test samples of hot gas to determine its viscosity and thermal conductivity. Argon was successfully tested at 20,000° F. Plans were made to use this method for research on diatomic gases and to increase temperatures to match entry conditions.

In other research on fluid properties studies were made of the chemical kinetics of carbon dioxide, a major constituent of the atmospheres of Mars and Venus. The dissociation rate of carbon dioxide up to 8,500° F. was established, and experiments were under way to extend the data to the even higher temperatures encountered at entry to Mars or Venus.

Electrophysics

The electrophysics program is designed to provide an understanding of the basic physical principles requisite for advances in such disciplines as electronics and propulsion. It involves theoretical and basic physics research on the properties and atomic electric behavior of solids, liquids, and gases acting under the influence of gravitational, nuclear, electric, and magnetic force fields.

In investigations of the basic electronic properties of fluorescent solids, a new and effective way was found to change the photoconductivity of a phosphor, such as cadmium sulfide, under illumination. Ordinarily, the electrical conductivity of optically excited cadmium sulfide is fixed by the crystal structure and purity of the sample and is not readily changed. However, by subjecting the cadmium sulfide to irradiation by a beam of slow neutrons from a reactor, the photoconductivity was changed depending upon the degree of neutron irradiation.

As a result of this work, it may be possible to adjust the photoconductivity in phosphors and photoconductors to meet various operating conditions.

Lewis Research Center conducted an experimental investigation of the critical current—critical magnetic field relationship for superconducting niobium tin deposited on a stainless steel ribbon kept at a temperature of —452° F. Experimental data indicated that at low values of current and magnetic fields, the niobium tin unexpectedly lost its superconductivity. When the ribbon was copper plated, the anomalous behavior was eliminated, and the ribbon operated at greater current-magnetic field values. It was planned to extend the work to superconducting coils in an effort to improve their behavior. At present, they lose their superconductivity at lower current than expected for a given magnetic field.

Experimental data obtained at Lewis Research Center indicated a fundamental difference in the nuclear structures of calcium 40 and argon 40. The research is to be continued to obtain data on the detailed nuclear structure of calcium and argon.

Materials

Ceramics Research.—Ceramics are widely used in the space program in many important applications. Consequently, it is necessary to emphasize basic research on ceramics so that they can be improved.

Studies were in progress on methods of synthesizing a single crystal of carefully controlled composition, of the thermodynamic relationships between ceramic compounds, of the relationship between the microstructure and the mechanical properties, and of the relationship between the atomic and electronic structure and the properties. In addition, relationships between the atomic structure, the electronic structure, and the mechanical strength were established.

Stress Corrosion of Titanium Alloys.—Screening studies of skin alloys for the Mach 3 supersonic transport were completed.

They indicated that the outstanding material for this application is a titanium base alloy containing 8 percent aluminum, 1 percent molybdenum, and 1 percent vanadium. This alloy has excellent strength at the operating conditions and is light in weight; its physical properties do not appear to deteriorate even after many thousands of hours at use stresses. However, stress-corrosion data is required to determine if the airplane skin can resist the corrosion effects of the salt used to clean runways in winter or picked up as spray from the oceans over which the aircraft is operating. Laboratory tests indicated that under certain accelerated conditions the alloy can fail catastrophically in very short periods of time, but the tests did not succeed in defining the mechanism of the damage.

A study of all the data on this subject led to the following conclusions: There appears to be a threshold value of temperature (in the vicinity of 500° F.) below which sea salt has no detrimental effect; high velocity air may reduce the damaging effects of sea salt; the temperature threshold should be precisely determined; and corrosion tests in which the specimens are subjected to high-velocity air stresses should be initiated.

Applied Mathematics

During the period, the Jet Propulsion Laboratory developed a new method for finding approximate solutions for systems of nonlinear differential equations, such as frequently arise when investigating higher order corrections to orbits in space. The method permits rectangular coordinates, which are especially convenient for machine computation, to be retained, thus greatly reducing the time and cost required for these necessary computations.

Ames Research Center developed a new mathematical approach to predicting the behavior of shock waves when they are resisted by radiation pressure. By utilizing a special kind of approximation method, direct numerical solutions to the integral equations involved were obtained. Temperature and velocity profiles of shock waves can now be computed with much greater ease and higher accuracy.

Under a NASA grant, methods were developed for obtaining numerical solutions of differential equations. Test computations using the new methods yielded solutions with less than 1 percent of the error of solutions found by conventional methods, and computing time was less.

Nuclear Propulsion and Power Generation

During the period, NASA continued research on nuclear and electric sources for possible propulsion and power generation applications. Work moved forward with SNAP–8 development (an AEC–NASA project), the nuclear electric power research and technology program, the electric propulsion program, and the nuclear rocket program.

The SNAP-8 Development Project

The objective of the SNAP–8 project is to develop a 35-kw nuclear electrical generating system capable of startup and continuous, unattended operation in space for 10,000 hours. Mission applications may include power for a manned orbital space station, a lunar station, manned or unmanned space probes, and communication satellites.

The SNAP–8 power system is being developed under a NASA contract. The nuclear reactor for SNAP–8 is being developed under an AEC contract. To reduce development problems and widen potential applications, the SNAP–8 power conversion system was redesigned to emphasize state-of-the-art technology and reliability, and to minimize component interdependence.

Extensive (60,000 hours) nonnuclear testing of power conversion system components was planned. Two 10,000-hour nuclear tests of the integrated SNAP–8 system were scheduled to be conducted in the AEC's Ground Prototype and Flight Prototype Test Facilities. Plans were made for operation of SNAP–8 in a simulated space environment at the NASA Plum Brook Space Propulsion Facility.

A definitive program was negotiated with the contractor for the ground development of SNAP–8. The program centered on separate design and testing of the power conversion system and on the nuclear system in order to obtain performance parameters of each prior to mating them for integrated system tests.

During the period, the fabrication and assembly of all major first model power conversion system components was nearing completion. The prototype alternator successfully passed initial electrical tests, and the first mercury loop for test of the turbine-alternator assembly was nearly completed. The feasibility of the seal-to-space was experimentally established. And the SNAP–8 experimental reactor was run at system power and temperature.

Nuclear Electric Power Research and Technology

The nuclear electric power subprogram deals with the contract and inhouse technology work needed to construct the energy conversion equipment of advanced nuclear electric power generating systems. These systems are intended for both electric rocket propulsion and future auxiliary power applications.

The systems are "advanced" in the sense that they weigh less, have more power, and operate longer than systems presently under development such as SNAP–8. Multimegawatts of electrical power will be required for propulsion power applications involving planetary probes and manned planetary expeditions. Multikilowatts of power will be required for nonpropulsive applications such as communication satellites, a lunar base, deep space communications, and space laboratories.

The principal energy conversion concepts being investigated are the Rankine cycle liquid metal systems, the Brayton cycle gas turbine systems, and the thermionic direct conversion systems. Other concepts are being explored to a lesser extent for special applications. For example, the Stirling piston engine concept is being considered for very low power uses.

The work in both gas and alkali metal rotating systems was entering a component testing phase during the period. Turbines, pumps, boilers, condensers, inert gas compressors, and electrical generators were being fabricated for performance and eventually endurance testing. Basic work on materials corrosion, bearings, seals, and heat transfer was continuing. The thermionic conversion program continued to be primarily concerned with materials compatibility investigations, and secondarily with basic thermionic physics.

As one accomplishment during the period, the bearings stability test rig at a contractor's Schenectady plant began experimental testing. Testing was completed on six journal bearing designs. The detailed data were the first of any significance ever obtained in the turbulent fluid flow region. Operation in this region results from the use of low viscosity lubricants such as water and liquid metals.

As another accomplishment, the 300-kw boiling heat transfer facility at the contractor's Cincinnati plant, operated about 2,100 hours with potassium. Data were obtained in the temperature range from 1,600–1,750° F., with qualities of almost 100 percent. In all, 170 test runs were made without inserts and 90 with inserts. Liquid potassium runs indicated that liquid heat transfer doubled with inserts.

The 100-kw refractory metal facility at the same plant, which has a temperature capability of up to 2,200° F., operated 2,500 hours above 1,600° F. Over one-half of this time was spent above 1,800° F. and up to 2,200° F. Forty test runs were performed with sodium with and without inserts, and 60 test runs with potassium and without inserts. The data were the first obtained under these conditions.

In a third area of progress, a two-stage potassium vapor turbine completed its pretesting with steam and air. The 3-megawatt (thermal) potassium turbine test facility completed shakedown at the contractor's plant. Testing of the convergent-divergent nozzle with potassium vapor was completed to obtain fluid dynamic properties. At the end of the period, the turbine facility had operated 75 hours at potassium vapor temperatures up to 1,580° F. The turbine is expected to be installed in February.

Evaluation of the columbium alloys Cb–1Zr and AS–55 as potassium containment materials in advanced space power systems showed that these alloys exhibited negligible corrosion after 5,000- and 10,000-hour exposures to boiling and condensing potassium at 2,000° F.

One contractor conducted an in-pile test at 3,200° F. on candidate thermionic emitter fuel materials. The fuels had vapor-deposited tungsten cladding, and tests were equivalent to about 1,200 hours of burnup. The fuels tested were uranium carbide-zirconium carbide solid solutions and dispersions of uranium oxide in tungsten. Voiding (space for expansion) was provided in the fuel forms. Although swelling of the high density UC–ZrC did occur, there was no measurable deformation of the cladding in the 30 specimens irradiated.

The Electric Propulsion (Electric Rocket Engine) Program

The objectives of NASA's electric propulsion program are to provide research data and technology for the development of both low and high power engines; to develop, test, and evaluate laboratory engine models; and to investigate advanced concepts of electric propulsion.

Many space mission studies have shown that electric propulsion systems could provide for an increase in payload of several orders of magnitude over that provided by conventional rocket systems. Typical space missions for which these electric propulsion systems could be applicable during the period 1967–75 are: position control of scientific and communication satellites; prime propulsion of unmanned spacecraft, scientific probes, solar and out-of-the-ecliptic probes; planetary exploration probes; lunar supply ferries; and prime propulsion of manned spacecraft.

The electric engine program includes a supporting research and technology program and four separate engine development areas in which engine models are built for either laboratory or space demonstration purposes. Each of these engine development areas includes the development of different engine concepts. The engine development areas are large ion engines (hundreds of kilowatts to tens of megawatts), large arc jet engines (30 kw to megawatts), large magnetoplasmadynamic engines (kilowatts to tens of megawatts), and small ion, resistojet, and arc engines (3 kw or less). The large engines are being designed for prime propulsion of spacecraft while the small engines are suitable for control of satellites.

Each of the engine categories—electrothermal (arc, resistojet), electrostatic (ion), and electromagnetic (MHD or plasma)—offers superior performance in a different range of specific impulse or thrust for different potential mission applications.

Supporting Research and Technology

The supporting research and technology program areas provide additional effort on major problems encountered in the development of experimental electric engines. They also develop instrumentation and investigate new areas and concepts.

Electrostatic Propulsion Research.—In the electrostatic thrust systems, particles (ions and colloids) are accelerated to high velocities by electrostatic electrodes. Electrostatic research provides additional data on means of generating ions (ionization), means of accelerating ions, electrical theory relating to effects of building up a space charge, and the composition and behavior of ion beams. Applied technology areas include the factors influencing fabrication of porous metal ion emitters, design of electrical circuitry and components, design of propellant feed and storage components, and selection of various materials.

Investigations to generate ions by bringing cesium or mercury in contact with a hot surface (surface contact ionization) showed that the condition of the ion emitters can limit the life of the ion engine. Preliminary results of such investigations indicated that sintering of spherical particles may provide an excellent ionizer. Effects of surface contaminants on porous tungsten ionizers such as nitrogen, hydrogen, oxygen, carbon, and zirconium were also studied.

The highly complex problem of attaining leak-free seals between the porous ion emitter and its support structure received continuing emphasis. Significant progress was made in techniques of construction and assembly of small ion engine (10 to 15 millipounds thrust at 6,000 to 9,000 seconds specific impulse).

The major obstacle in attaining long ion engine operating life is sputtering erosion of the accelerator electrodes. A fundamental study was being conducted using electrode materials, propellants, and voltage differences typical of ion engines.

Electrothermal Propulsion Research.—The electrothermal engines (arc jet and resistojet) develop thrust by electrically heating a gaseous propellant such as hydrogen and expanding it through a nozzle. Studies were being conducted on components and basic processes. These included geometry of the electrodes required to generate the electric arc that heats the propellant; the process of converting electrical energy to thrust energy; the physical mechanisms which transfer heat from the propellant gases to the surrounding walls of the accelerator or electrodes; the selection of propellants and methods of storing them; and electrical circuitry.

A major goal is to develop long life arc jet thrustors. Such development will depend upon efficient regenerative cooling; this, in turn, depends on understanding the heat flow patterns and the mechanisms which influence them.

Another important problem area in arc jet thrustor operation is the loss of energy due to dissociation and ionization of the propellant atoms.

Studies were undertaken to find means of recovering the energy lost in these processes. One study resulted in the discovery of effective catalysts that can increase recombination rates at low temperatures. Additional work must be done at high temperatures so that the performance of arc jet engines can be improved at the high impulse, high power level regimes.

Electromagnetic Propulsion Research.—The electromagnetic or magnetohydrodynamic (MHD) engine concepts develop thrust by accelerating a gaseous propellant plasma such as argon or hydrogen by coupled electric and magnetic field forces. The objective of research in this field is to conduct feasibility studies of promising types of engine system concepts for propulsion application. These studies place considerable effort on such areas as the physics of plasma production and acceleration processes.

Laboratory data on a 10-kw repetitively pulsed coaxial accelerator indicated power efficiencies of 40 to 45 percent at 6,000 seconds specific impulse. This MHD engine concept shows promise for early electric propulsion application. Other MHD engine concepts which show promise are a Hall-current accelerator, a microwave cyclotron resonance accelerator, and a traveling wave accelerator. At Princeton University, studies were continued of the fundamentals of electrical discharge in plasmas and the generation and acceleration of a plasma in a converging thrustor chamber. Results so far indicate that the pulsed device now in operation may be converted to a high repetition rate, continuous wave acceleration which should function like a steady flow machine.

Component Technology.—Component technology studies continued to provide data on the requirements of electric propulsion system components to assure high performance, long life, reliability, minimum weight, and small size. These data are required for design tradeoffs between the electric thrustors, the power conditioning, the switching equipment, and the power supply system to obtain optimum electric propulsion systems capability. These studies are also expected to appraise the present state of component technology and define design requirements for components which will be needed in the next 5 to 10 years.

Experimental Electric Engine Development

The current primary goals are to develop design concepts and generate the technology of the thrustor and its components.

Large Ion Engines.—The large ion engine program is comprised of two separate experimental engine development programs: (1) a contact engine program, and (2) an electron bombardment engine program. The surface contact ion engine continued to show promise of yielding highest overall engine efficiency for specific impulse values above about 7,000 seconds. This engine type is therefore the most likely choice for use with lightweight electric power generating systems on interplanetary missions.

The electron bombardment ion engine offers the highest efficiency in the intermediate range of specific impulse from about 4,000 seconds up to 7,000 seconds. This engine type is the most likely choice for use on early interplanetary missions even with fairly heavy electric power generating systems. In this program, NASA is seeking to develop large ion engine systems (multi-kilowatt to 15 megawatts) for missions in cislunar and planetary space.

To develop reliable, high power ion engines, NASA must first develop low power engine modules and systematically scale or cluster these into the high power levels. By this building block technique NASA hopes to attain megawatt power propulsion systems.

Surface Contact Ion Engine Status.—During Phase I and Phase II of the ion engine program, a contractor designed, fabricated, and tested for NASA a 0.5 kilowatt or 3 millipound thrust circular-strip type surface contact ion engine; it provided 40 percent efficiency at a specific impulse of 4,500 seconds and operated for more than 200 hours. Subsequently, this engine module was scaled into a 2.5-kilowatt power level size.

The contractor also conducted studies on another type surface contact ion engine, called the linear-strip type. The linear-strip engine presented fewer engineering problems for scaling than the circular-strip engine, yet was comparable in efficiency. Eventually this 2.5 kw linear-strip engine will be clustered to attain the next power level plateau of 30 kw.

Electron Bombardment Ion Engine Status.—Also, during Phase II, another contractor designed and developed a 3 kw cesium electron bombardment ion engine for NASA. This engine design evolved from research at NASA's Lewis Research Center on a 0.5 kw mercury electron bombardment ion engine which provided 70 percent efficiency at 5,000 seconds specific impulse. This concept shows good performance between 4,500 and 7,000 seconds specific impulse. The principal development difficulty is designing an electron-producing cathode with long life.

A 1 kw contractor-developed cesium contact ion engine and a Lewis Research Center electron bombardment ion engine were scheduled for ballistic flight tests from the Wallops Station. These tests, planned for the latter half of 1964, were expected to determine whether ion engines can operate in a true space environment.

During the preceding report period, a test spacecraft containing the above engine began flight simulation tests in a vacuum tank at the Lewis Research Center. This payload was operated from the identical mobile equipment which is to be used at the Wallops Station during the flight tests. During the initial tests in this tank, the ion engine power converters failed, resulting in a lengthy R&D ground test program on power converters.

During the period of this report, the power converter problem was resolved and successful tests, simulating the complete flight sequence, were conducted in the vacuum tank. Following repeated tests to insure reliability, the spacecraft integration contractor started to assemble the final prototype and flight spacecraft to meet the launch date.

Large Arc Jet Engines.—The objective of this program is to develop experimental arc jet thrustors in the 30-kw to 40-mw power range in order to provide the technology for scaling from small engines to the sizes that will be useful in future mission applications. These are missions that require maintaining or transferring relatively large systems such as space laboratories or communication satellites from one orbit to another orbit. Such missions may also include propulsion of freighter ferries for cislunar missions.

A DC 30-kw arc jet engine was designed and fabricated under contract for NASA and was successfully demonstrated for 700 hours continuous running in the contractor's vacuum tank. There was no apparent electrode erosion, component deterioration, or significant malfunction. Engine efficiency was 45 percent at a specific impulse between 1,000 and 1,350 seconds.

During the period, a 250 kilowatt radiation-cooled engine was operated with a specific impulse of 2,200 seconds at an efficiency of better than 35 percent. This work led to a re-evaluation of arc jet performance limitations. It appears that the engine efficiencies can be improved in the high specific impulse range of 2,000 to 22,500 seconds.

Small Ion, Arc, and Resistojet (200 Watts to 10 Kw) Engines.—The objective of the small electric rocket engine program is to develop thrustors which will have long life, high reliability, and the capability for a large number of restarts over a period of several months or years. These engine systems must be capable of being integrated in a three axis attitude control and station keeping system.

Under one particular contract, NASA was developing a small ion engine scheduled for laboratory demonstration by September 1964. Considerable effort was being placed on an analysis of the ion source and electrode geometry.

Under another contract, the Agency was developing a small resistance-heated jet thrustor. For this thrustor, plans were made for the laboratory life test demonstration and for research on the problems associated with propellant storage, electrical circuitry, and electronic equipment breakdown under true space environmental conditions.

The Nuclear Rocket Program (Rover)

The Nuclear Rocket Program is a joint AEC–NASA effort to develop nuclear propulsion systems and related technology for space vehicle application. Such engines, will be needed to conduct high energy missions such as the extensive exploration of the moon, the establishment of a lunar base, and the landing of men and equipment on Mars for studies of that planet. Nuclear propulsion may also provide the energy needed to send unmanned vehicles throughout the solar system with the equipment needed to measure, record, and transmit observations to the earth.

NASA has primary responsibility for the research and development work on nonreactor components and for integrating the reactor into the engine. AEC is responsible for the research and development of reactors and reactor components required for the propulsion systems specified by NASA. Management of the Nuclear Rocket Propulsion Program, with the exception of the inflight testing of reactors (Project RIFT), is the responsibility of the joint AEC–NASA Space Nuclear Propulsion Office (SNPO).

At the end of 1963, emphasis of the program shifted to establishing and demonstrating nuclear rocket technology, solving technological problems by operation of nuclear rocket reactors and engine systems, and providing hardware that could lead to flight applications. The ultimate objective is to develop nuclear rockets for advanced space missions.

As a result of this reorientation, that portion of the RIFT project under contract was cancelled. The KIWI project (p. 144) remained essentially unchanged and was phasing over to the higher powered PHOEBUS system of advanced graphite reactors. The NERVA project was reoriented toward those areas expected to pace the development of flight systems so that flight hardware can be rapidly developed with assurance when the requirement exists. The NERVA program includes testing of nuclear rocket reactors and experimental engine systems.

NERVA (Nuclear Engine for Rocket Vehicle Application)

The NERVA project—comprising the nuclear reactor, the nonnuclear components, and their system integration—is concerned with the development of a nuclear rocket engine for rocket vehicle application.

During the current reporting period, the contractors continued to concentrate on the development of the reactor and on the design and development of critical engine system components. Progress included the assembly and shipment of the first NERVA type cold flow reactor, designated NRX–A1–CF, to the Nuclear Rocket Development Station (NRDS), Nevada, for cold flow testing; the successful fabrication and hydrotesting of the first NRX–A cold flow nozzle and pressure vessel; and the beginning of fabrication of fuel elements for the first NERVA hot reactor.

The NRX–A1–CF was being prepared for tests at NRDS. In addition, the prime contractor established and activated facilities for testing nonnuclear engine components such as the liquid-hydrogen cooled bearings of the engine turbopump system; and the sensors, actuators, and valves of the engine control and monitoring systems. The principal subcontractor assembled and activated a vibration test unit for simulating expected vibrations on full-scale reactors. Recent tests on this unit showed that the current structural configuration of the NRX–A reactor can withstand these stresses. Additional contractor test facilities were prepared as a part of the overall component test program.

KIWI Project

The KIWI project, being carried out by the Los Alamos Scientific Laboratory (LASL), is concerned with the development of the reactor technology upon which the NERVA engine will be based. During the current reporting period, two series of cold flow tests were conducted on extensively instrumented KIWI–B2 and KIWI–B4 reactor designs, designated the KIWI–B2A–CF and the KIWI–B4B–CF. The KIWI–B2A–CF tests, were designed to investigate a particular support concept. Results of the tests were satisfactory as no vibrations were observed.

The KIWI–B4B tests were conducted to confirm that the design modifications being incorporated in the KIWI–B4-type reactor would eliminate vibrations experienced in previous tests. These, together with extensive analytical and component tests, confirmed that the design modifications would prevent the core vibrations encountered, at least under cold flow conditions. The KIWI–B4D–CF reactor which incorporates all design modifications was assembled at NRDS and was being prepared for cold flow testing.

In addition, the criticality assembly of the KIWI–B4D hot reactor was completed and the first criticality check was run.

Advanced Research and Technology, Propulsion and Vehicles

The Advanced Research and Technology effort is concerned with establishing the necessary technical information for the design and operation of nuclear rocket engines and components, with providing the basic technology for the development of future engines and components, and with evaluating the feasibility of advanced nuclear program concepts.

In the reactor area, guidelines were established for the advanced graphite reactor program called PHOEBUS which will become the prime concern of the Los Alamos Scientific Laboratory (LASL) as the KIWI project phases out. The PHOEBUS effort should provide the necessary technology for designing rocket reactors with higher power levels, longer operating times, increased restart capability, and higher temperatures.

In reactor physics, LASL was conducting critical experiments on larger diameter cores which will be used in the PHOEBUS program.

LASL was also examining some of the problems associated with operating nuclear rocket engines in a cluster. The ability to cluster nuclear rocket engines could provide great flexibility in the development of nuclear propulsion systems to meet the requirements for space missions and greatly increase reliability for these missions. An important test to determine the influence of one reactor on another in a cluster was scheduled at LASL for the spring of 1964. In this test, a series of measurements will be made of two clustered zero power critical reactors to determine nuclear interactions.

The Argonne National Laboratory and the Lewis Research Center continued to conduct research on tungsten reactor concepts. During the time covered by this report, a fast tungsten reactor concept and a thermal reactor concept were investigated. The tungsten systems may have performance potential in attributes such as long operating life and restart capability which make them worthwhile for further consideration.

Continued progress was made in providing the necessary facilities for nonnuclear component and engine system testing. The program to develop a feed system (two turbopumps operating in parallel) for the ground test of high powered reactors moved forward with successful tests of both pump and turbines at rated speeds. In addition, studies of nuclear rocket nozzles were made to determine the compatibility of present nozzle technology with the performance goals of the PHOEBUS program, and to explore the possibility of using uncooled nozzles for nuclear rockets. Work was also underway on the development of bearings, actuators, and control components for advanced nuclear rocket engines.

In vehicle technology, tests were completed on a tank containing liquid hydrogen heated by nuclear radiation. A 150-gallon test tank inserted over a test reactor was used to simulate the anticipated radiation field from an actual nuclear rocket engine situated below the propellant tank.

In another test, work was initiated to measure neutron cross sections in liquid hydrogen. This work will provide data to assist in computing propellant temperature rise due to neutron leakage from the nuclear rocket engine.

RIFT (Reactor In-Flight Test) Project

As in the previous period, the RIFT project proceeded at a controlled pace without any major hardware or facility commitments. All efforts was directed towards the orderly detection and solution of design, tooling, and development problems. As a result of the redirection of the entire nuclear rocket program to a ground experimental system approach from the earlier flight oriented effort, RIFT contract termination proceedings were initiated on December 24, 1963.

Prior to termination of the RIFT contract, work had been initiated on various hydrogen tank insulation materials, using a 5-foot-diameter tank and the cryogenic facility which was activated during the preceding period. One shakedown test was completed; it indicated the need for substantial work on insulation and instrumentation techniques.

The RIFT experimental tool program yielded valuable data on welding materials and techniques. In particular, it was determined that welding deficiencies were attributable to voids and craters in the weld wire. Information from this effort was fed into the Saturn V development program.

The Moffett Field airship hangar was officially turned over to NASA by the Navy for ultimate use as a RIFT fabrication facility. Units of tooling being used to fabricate test panels and develop welding techniques were moved into the hangar. However, the contract termination halted all such RIFT planning, and future use of the hangar was under study at the end of the period.

The Nuclear Rocket Development Station (NRDS)

Construction at the NRDS Nevada site was progressing satisfactorily. Work on Engine Test Stand No. 1 and the engine maintenance assembly and disassembly building continued.

Reactor Test Cell A was modified to equip it for testing NRX (NERVA-type cold flow) reactors. Major changes included an increase in liquid hydrogen storage capacity to permit longer operating times and a mixing chamber to permit selection of the temperature and quantity of hydrogen entering a reactor over a suitable range. Reactor Test Cell C, which began operation in June 1963, was used for the KIWI–B2A and the KIWI–B4B cold flow tests.

A contractor was selected to perform design services on a proposed modification to Test Cell C. This modification will permit the conduct of higher power reactor tests. The contractor began a conceptual study on a proposed new test cell, Test Cell E, which will be required for reactor tests in the 10,000- to 20,000-mw power level range. Contracts were awarded in December, and construction started on the engineering administration building and a warehouse and shops building.

Tracking and Data Acquisition

During the second half of 1963, NASA continued to expand, modify, and improve its tracking and data acquisition network to satisfy new mission requirements. Installation of new equipment and construction of facilities to support future flight missions progressed as planned.

The Manned Space Flight Network, the Deep Space Network, and the Satellite Network gave tracking and data acquisition support to the successful launch of the Centaur vehicle (AC–2) on November 27. The Satellite Network operationally supported 29 satellites; eight of these were launched after July 1, 1963.

Manned Space Flight Network

The Manned Space Flight Network, a world-wide tracking and data acquisition network, now consists of the following stations:

Primary	*Secondary*
Cape Kennedy	Kano
Bermuda	Zanzibar
Canary Island	Canton
Carnarvon	Point Arguello
Hawaii	White Sands Missile Range
Guaymas	Eglin AFB
Texas	
Rose Knot Victor	
Coastal Sentry Quebec	

Each of the primary stations must be able to track, command, receive telemetered data, and communicate with the astronaut and the Gemini Target Vehicle (Agena D) with extremely high reliability. This tracking and telemetry information must be immediately and continuously available to the control centers so that corrective action can be taken should emergencies arise during a mission.

To prepare the network for what is now its prime objective—the acquisition of flight data from the Gemini capsule and the Agena Target Vehicle—the Manned Space Flight Network was being modified. Modifications included radar tracking systems to provide position and velocity information on the spacecraft; telemetry systems to receive the data stored on board the vehicle and to monitor the performance of the spacecraft systems; command equipment to allow control of the systems and spacecraft; and additional voice communications to provide the vital link between ground flight control and the astronauts.

The radar system for the Gemini program will consist of C- and S-band radars; both C- and S-band beacons will be installed on the two spacecraft. Near simultaneous tracking of the capsule and target vehicle will be achieved by using either the C- or S-band beacon and a vehicle identifying code. The C- and S-band radars will be capable of tracking the Gemini spacecraft and the Target Vehicle sequentially with positive identification of both vehicles. Reentry will be covered by C-band radar only because the S-band beacon is jettisoned after retrofire.

A digital telemetry system known as Pulse Code Modulation (PCM) will be used to transmit data from the Gemini spacecraft and the Target Vehicle to the ground stations. Each primary ground station will be capable of receiving, recording, and simultaneously processing and displaying the real time or stored PCM information from both spacecraft. A flexible real time display system was being installed which will allow multiple selection of Gemini data for display. Equipment is designed to allow changes to be made in the displays at any time without disrupting the continuity of the operation.

Command data will be transmitted to the spacecraft by a digital command system. Digital data will be transmitted to on-board equipment and voice data to the astronaut. As now planned, a total of 200 different command words may be transmitted to the spacecraft and 96 different command words to the Target Vehicle. All commands will be automatically verified.

Separate HF and UHF frequency range voice transmission systems will enable both astronauts to transmit to the ground stations at the same time, each using one of the systems.

On-site data processing capability will be provided by a digital-to-teletype conversion system able to select, convert, and transmit telemetry information in teletype form, in near real-time, using a method compatible with existing communication circuits. The PCM ground station will furnish all data outputs to the data processor system which will select the required data as programed by the flight controller and route the selected data to the conversion device.

Also in this period, NASA continued to develop network tracking and data acquisition requirements to support the Apollo program, including new and advanced ground support instrumentation, antennas, and specially instrumented ships.

The major event supported by the Manned Space Flight Network was the Centaur AC–2 flight test. Telemetry returns were excellent during the early part of the flight along the Atlantic Missile Range chain of tracking stations. Flight data received by the Networks showed that nearly every phase of the operation approximated planned performance. Several space firsts were associated with this flight: this was the first time it was possible (by using telemetry) to evaluate in space the guidance system which will eventually control all Centaur flights; this was also the first successful flight of the straight side Atlas and the strengthened Centaur stage; and it was the first major test of the "Glo-Trac System"—a precision electronic range and rate type tracking system.

Deep Space Network

The Deep Space Network stations were modified with special equipment to meet the spacecraft requirements for the Ranger Block III flights scheduled to take place during 1964. The control room at Johannesburg, South Africa was altered to provide additional floor space to accommodate special supporting equipment for the Ranger and Mariner spacecraft. At the stations, work continued simultaneously on S-band and L-band equipment to meet the respective requirements of the Mariner C spacecraft and the Ranger series. The antenna model range was operated extensively in antenna calibration pattern tests.

To maintain the network at optimum performance level, key personnel from all stations were trained at the Goldstone complex in the operation and maintenance of new equipment; in turn these personnel trained other personnel at their home stations.

Communication circuits between the Jet Propulsion Laboratory, Pasadena, Calif., and Woomera, Australia, were converted from high frequency radio to submarine cable; a significant improvement in reliability resulted.

Also during this period, construction was started on the S-band prototype 210-foot parabolic antenna station at Goldstone, Calif., and construction of the 85-foot antenna station at Canberra, Australia, progressed according to schedule. Planning continued for an 85-foot antenna station to be located in Southern Europe.

Extensive tests and checkouts of the network were conducted to improve overall operating procedures; the network provided support for the Interplanetary Monitoring Platform (S–74) and Centaur (AC–2) missions. These missions demonstrated the network's flexibility in providing tracking and data acquisition support for near-earth satellites as well as for the lunar and planetary missions for which it was designed.

Satellite Network

The Satellite Network consists of 13 electronic stations operated by the Goddard Space Flight Center and 12 optical stations operated by the Smithsonian Astrophysical Observatory. The electronic stations provide principal tracking and data acquisition support; the optical stations provide backup support during early-launch phases of the satellites.

Present stations are at Blossom Point, Md.; Fort Myers, Fla.; Quito, Ecuador; Lima, Peru; Santiago, Chile; Woomera, Australia; Johannesburg, South Africa; Goldstone, Calif.; St. Johns, Newfoundland; East Grand Forks, Minn.; Winkfield, England; Fairbanks, Alaska; and Rosman, N.C. Station operations at Antofagasta, Chile, were terminated in July 1963 as part of a continuing program to improve the network and eliminate redundancy.

The network was improved by the addition of equipment to meet requirements for supporting larger and more complex satellites which will use very wide bandwidths and will require very high-gain antennas at the ground stations. Two such 85-foot parabolic antennas are in operation at stations near Fairbanks, Alaska, and Rosman. Planning was underway for the installation of a second similar antenna at Rosman, and one at Canberra, Australia. As these become operational, the network will have the necessary capability to fully support new satellites such as the Orbiting Astronomical Observatory, Eccentric Geophysical Observatory, Polar Orbiting Geophysical Observatory, and Nimbus.

The electronic Satellite Network supported a total of 29 satellite programs during this period, including the following new NASA satellites:

Name	*Date Launched*
Syncom II	July 26, 1963
Explorer XVIII	Nov. 27, 1963
Explorer XIX	Dec. 19, 1963
TIROS VIII	Dec. 21, 1963

Four other new satellites were supported by the network:

Tetrahedral	July 19, 1963
Tetrahedral	July 19, 1963
SN-39	Sept. 28, 1963
TRS 2	Oct. 17, 1963

Backup support was provided by the 12 optical tracking stations operated by the Smithsonian Astrophysical Observatory in San Fernando, Spain; Mitaka (Tokyo), Japan; Niani Tal, India; Arequipa, Peru; Shiraz, Iran; Curacao, Netherland West Indies; Villa Dolores, Argentina; Mount Halaekala, Hawaii; Olifantsfontein, South Africa; Woomera, Australia; Jupiter, Fla.; and Organ Pass, N.M.

During this report period, the optical tracking stations provided orbital data for nine satellites and tracked 13 other satellites to obtain data for the precise measurement of atmospheric and magnetic properties affecting the satellite orbits.

International Programs

International cooperation in the peaceful uses of outer space continued to expand during the last half of 1963. By the end of the year, 67 political jurisdictions either were or had been associated with NASA in space research.

The growth of international cooperation was marked by new joint satellite programs, continuing cooperative sounding rocket projects, the organization of a multination investigation of weather systems in the Indian Ocean region, and expanded accommodation of U.S. overseas network operations. A new form of reciprocity was introduced when France's offer to launch U.S. payloads on French rockets at a French range was accepted by NASA.

NASA's international activities are graphically summarized in appendix N (p. 229), which shows, by country, foreign participation in flight and ground-based cooperative projects, support of NASA's overseas operations, and personnel exchanges and training programs.

Cooperative Projects

In the last half of 1963, NASA agreed to new cooperative arrangements with the following countries: Canada, France, India, Pakistan, and the United Kingdom. Also, the Agency continued its cooperative projects with Italy, Japan, Norway, Sweden, Denmark, and the U.S.S.R.

Canada

On December 23, NASA and the Canadian Defence Research Board (DRB) signed a Memorandum of Understanding providing for a joint ionospheric monitoring program; this program is to consist of four scientific satellites to be built by DRB and launched by NASA at appropriate intervals between 1965 and the next solar maximum in 1970. The program continues the close Canada-United States cooperation which produced Alouette, the successful Canadian topside sounder satellite launched by NASA in September 1962.

France

Two French payloads were successfully launched on NASA Aerobee rockets from Wallops Island in October. These launches were part of a cooperative project between NASA and the French National Center for Space Research (CNES) for the study of very low frequency (VLF) radio propagation. If the scientific results of the sounding rocket experiments warrant inclusion of the VLF experiment on a satellite, NASA will supply a Scout vehicle to launch a satellite constructed by CNES.

In a reversal of cooperative roles, NASA made plans to fly U.S. payloads on French rockets at a French range. This program will entail two cooperative launchings from the Hammaguir range in Algeria; these launchings will carry joint experiments from the Goddard Space Flight Center and CNES to measure simultaneously electron and ion temperatures in the upper atmosphere.

A French experiment to measure the sun's spectrum was selected by NASA in August for inclusion on the Orbiting Solar Observatory-E spacecraft.

India and Pakistan

During the reporting period, NASA concluded agreements with both India and Pakistan providing for meteorological rocket soundings over the next year. These will be part of a comprehensive study of the Indian Ocean's weather patterns. Arrangements have been made for the United Kingdom and Australia to participate. The program will supplement weather investigations conducted in the course of the International Indian Ocean Expedition.

As part of a NASA-India cooperative project, the first in a series of four planned sodium vapor payloads was successfully launched in November on a Nike-Apache rocket. The launch took place from the newly established rocket range at Thumba in southern India. This rocket range is expected to be sponsored by the United Nations.

Italy

A successful flight test of the principal component of the cooperative San Marco satellite was conducted August 3 on a Shotput sounding rocket launched from Wallops Island by an Italian crew. (Fig. 7–1.) The component tested was a drag balance mechanism designed to measure atmospheric density. The flight was the second step in Phase I of a three-phase program which is to culminate in launching the San Marco satellite into equatorial orbit from a mobile platform. As a next step in Phase I, a Shotput launching is expected to be conducted in 1964 to test the platform in equatorial waters.

Figure 7–1. Italian flag raised at Wallops prior to launching of Shotput sounding rocket.

Japan

In an extension of a cooperative project, experiments designed to compare Japanese and NASA ionospheric measurement instrumentation were successfully launched from Wallops Island September 25 and 28 on Aerobee rockets. A further flight employing a Javelin rocket was scheduled for June 1964.

Norway-Denmark

On September 12, a joint NASA-Norwegian-Danish ionospheric payload was successfully launched on a Nike-Apache sounding rocket from the Norwegian range at Andoya, north of the Arctic Circle. Further launchings in the cooperative program were scheduled for early 1964, also at Andoya.

Sweden

As a continuation of experiments conducted in the summers of 1961, 1962, and 1963, four cooperative sounding rockets carrying grenade experiments were successfully launched at Kronogard, Sweden, in July and August. This cooperative NASA-Swedish Space Committee project is part of a program designed to investigate the origin and nature of noctilucent clouds.

In another joint project, three ionospheric payloads designed and built by the Uppsala Observatory (Sweden) were launched from the White Sands Missile Range in October and December on boosted Arcas rockets.

United Kingdom

Following the successful launching of the Ariel I satellite in April 1962, work continued on the second cooperative satellite (the UK–2), scheduled for launching early in 1964. In addition, NASA and the British National Committee for Space Research reached agreement on arrangements for a third joint NASA–U.K. satellite (S–53) to be launched by NASA late in 1966. In this project, the British will assume responsibility for designing, constructing, testing, and delivering a flight-qualified spacecraft to the launching site.

U.S.S.R

On August 1, the Soviet Academy of Sciences approved a Memorandum of Understanding, worked out during the previous spring by technical teams led by NASA Deputy Administrator Hugh L. Dryden and Soviet Academician A. A. Blagonravov. This Memorandum sets forth details for implementation of the cooperative space projects agreed to earlier in the fields of satellite meteorology, geomagnetic measurement by satellite, and joint tests of long distance telecommunications using the Echo II passive communications satellite.

Communication was maintained, although the Soviet side did not meet the agreed time schedules. The first important test of Soviet performance under this program is in connection with the launching of the passive communications satellite, Echo II, on January 25, 1964.

Laser Tracking Experiment

The British National Committee on Space Research (BNCSR) and the French National Center for Space Research (CNES) agreed to participate in a laser tracking experiment associated with the S–66 satellite. The British and the French will supply the necessary ground equipment; NASA will furnish orbital data needed to point the lasers at the satellite, presently scheduled for launching in early 1964.

Weather Satellite

Seven foreign civilian Automatic Picture Transmission (APT) ground sets were reported operational following the launching of the TIROS VIII weather satellite on December 21. This equipment allows users to obtain direct readout of local cloud photography as the satellite passes overhead. (See ch. 3 for details on APT.) Sets in France and the International Indian Ocean Expedition Headquarters in India were purchased from the NASA contractor. Those in Australia, Canada, Denmark, Hong Kong and the United Kingdom were built locally, based on NASA-supplied technical information.

Operations Support

During this period, intergovernmental agreements were concluded with Australia, Malagasy and the United Kingdom, providing either for new facilities in the NASA tracking and data acquisition networks or for continued use of existing facilities. Additionally, arrangements were made with Canada, Nigeria, Denmark, Norway, and Sweden for cooperation in the testing of experimental communications satellites. Also, negotiations were initiated with Spain for a new station for primary support of deep space probes.

Australia

The Australian-United States intergovernmental tracking station agreement was amended on October 22 to provide for a wideband command and data acquisition facility to be constructed near Canberra. The station will be used to support the advanced observatory satellites.

Malagasy

Agreement with the Malagasy Republic was obtained on October 7 for a NASA injection monitoring station to be placed near Majunga. The station is intended to be used initially in support of the Echo II, S–48, and Nimbus satellites.

Bermuda and Canton Island

On September 23, NASA obtained amendments to agreements with the United Kingdom for tracking stations in Bermuda and Canton Island. These amendments make these stations available for support of unmanned as well as manned satellite programs. The Bermuda station has already been used in this broadened capacity. The duration of the Canton Island agreement was extended for a period of 8 years.

Canada

An exchange of diplomatic notes on August 23 between the United States and Canada confirmed a Memorandum of Understanding between NASA and the Canadian Department of Transport for cooperation in the testing of experimental communications satellites.

Nigeria

Through the Department of State, NASA arranged with the Nigerian Government for the USNS *Kingsport* to return to Lagos Harbor in July to serve as a ground terminal in support of the Syncom II project. On August 23, the first intercontinental telephone and radio demonstration between Africa and the United States via communications satellite (Syncom) was conducted. Officials of the United States and the Nigerian Governments, including President Kennedy and Prime Minister Balewa participated in the half-hour program.

Scandinavia (Norway, Denmark, Sweden)

In Copenhagen on September 14, President Johnson (then Vice President) participated in an exchange of diplomatic notes between the United States and Denmark. These and other notes exchanged with Norway and Sweden confirmed a Memorandum of Understanding between NASA and the Scandinavian Committee for Satellite Telecommunication. The memorandum provided for cooperation in the testing of experimental communications satellites.

Spain

Negotiations were initiated with Spain in late August for a tracking and data acquisition station to be established approximately 30 miles west of Madrid. The station is intended to support the lunar and planetary exploration program. It will also be able to supplement NASA's manned space flight network, as needed.

Cooperation Through International Organizations

NASA continued its support of U.S. interests at international forums on outer space. The Agency participated in the work of the United Nations Committee on the Peaceful Uses of Outer Space and, through the National Academy of Sciences, in the work of the

Committee on Space Research of the International Council of Scientific Unions.

Personnel Exchanges, Education, and Training

During the last half of 1963, over 1,000 foreign nationals visited NASA facilities for scientific and technical discussion or general orientation. Visitors included representatives of space programs in Belgium, Brazil, France, Italy, Japan, Norway, Pakistan, and United Kingdom, as well as representatives of the European Space Research Organization (ESRO) and the European Launcher Development Organization (ELDO).

In this report period, 36 graduate students from 12 countries studied space sciences at 15 American universities under the NASA International University Fellowship program. This program is administered by the National Academy of Sciences. Also in this period, 54 postdoctoral and senior postdoctoral associates from eighteen countries performed research at NASA centers, including JPL. This program is administered by the National Academy of Sciences, with JPL administering its own program. (Both programs are open to United States nationals also.)

During this period, 98 technicians from 5 countries and ESRO, here at their own expense, received training in space technology at Goddard Space Flight Center, Langley Research Center, and Wallops Station in connection with agreed international cooperative projects.

University and Basic Research Programs

NASA supports a wide variety of research in space-related sciences and technology conducted by universities and nonprofit organizations. This research may take the form of specific projects or broad multidisciplinary programs and range from basic investigations to technological applications.

The Agency relies heavily on the university for fundamental and ground-based research in support of space flight; for example, research in energy conversion to develop improved fuel cells or basic studies of high-strength materials for spacecraft. Universities also conduct some flight experiments with satellites and space probes.

Accordingly, many of the scientific and technological advances recorded in this report were made possible through NASA-sponsored university research.

Basic research in space science and technology is supported by the Agency in response to unsolicited research proposals from scientists. NASA's Grants and Research Contracts Division is the focal point for receiving, handling, and distributing these proposals, and for issuing research grants and contracts. (A brochure providing information on procedures for submitting research proposals is available from the Office of Grants and Research Contracts, National Aeronautics and Space Administration, Washington, D.C., 20546.)

Grants and Research Contracts

During the last six months of 1963, 1,568 proposals for research support were received. In addition, 242 proposals were supported by NASA totaling $34,958,281 and distributed as follows:

Educational institutions	$23,352,299
Nonprofit scientific institutions	5,645,867
Industrial organizations	109,272
Other Federal agencies	5,850,843

Active grants and research contracts for this report period are listed in appendix M.

Sustaining University Program

NASA's sustaining university program was inaugurated in 1962 to increase university participation in aeronautical and space sciences and engineering, thereby strengthening Agency-sponsored research to best serve the Nation's rapidly expanding space program.

This program has as its objectives: increasing the future supply of engineers and scientists trained in space-related areas; assisting universities to provide additional research facilities for conducting space research; and encouraging new, creative research approaches, developing new research capabilities, and consolidating related research activities. Training, facilities, and research are its three basic elements.

Training

To increase the supply of scientists and engineers, NASA makes training grants to universities in support of outstanding predoctoral graduate students in space sciences and engineering. (The universities may also receive an allowance to strengthen their programs in this field.)

During this report period, 786 predoctoral graduate students entered training under grants to 88 universities, bringing the total number of students in training to 886. The first 10 grants to 10 universities for the training of 100 students were made in April 1962.

Facilities

Inadequate or nonexistent research laboratories at many institutions impede research and training in space science and technology. To provide needed research space at institutions heavily involved in NASA's programs or which have a unique research capability required for the space effort, the Agency provides grants to allow construction of additional facilities.

Fifteen institutions were recipients of grants to construct 500,000 square feet of research space by the end of 1963. In addition, during the report period a biomedical annex to the cyclotron at Harvard University was completed and in operation.

Research

Recognizing an urgent need to expand and improve the capabilities of the Nation's universities to conduct research in the space sciences and technology, NASA—through its sustaining university program—is supporting broad programs of research specifically tailored to each university. This approach affords universities the maximum opportunity to adopt new research approaches to meet rapidly changing requirements, balance and strengthen existing areas of space-related work, and stimulate the development and growth of new ideas and talent.

In addition, by supporting quality research at selected institutions not currently participating in space research, the number of institutions involved in the space program is permitted to grow and thus broaden the base of the country's total research resources. In fiscal year 1963, for example, 25 grants of this type were awarded to as many institutions; and 4 new programs were initiated at 4 additional institutions during the report period.

Informational Programs

To keep pace with the accelerated national space programs, NASA, from July through December 1963, expanded its informational-educational activities and services.

Among key developments of the period were:

- Establishment of educational services programs at several Agency centers and regional offices, including expansion of the spacemobile program, which provided over 1 million school children and adults with information on space science and technology during the last 6 months.
- Joint participation with the Defense Department and with sponsors of the 1964–65 New York World's Fair in setting up a U.S. Space Park featuring the most impressive collection of full-scale NASA and Air Force spacecraft and rockets ever assembled outside of Cape Kennedy.
- Testing of a Selective Dissemination of Information system which promises to become one of the world's most advanced in the scientific and technical information field.
- Publication of over 400 scientific and technical reports on NASA's research and development work—a 30-percent increase over those issued for a comparable period in the past.

Educational Programs and Services

Making its educational services more responsive to the needs of the Nation's teachers and students, NASA took two organizational steps during the report period. The Agency helped several of its field installations establish regional educational services programs—assisted by spacemobiles—comparable to those at headquarters. (Six centers and offices now have educational services sections.) In addition, the spacemobile program was expanded to meet the heavy demands of schools for space science lecture-demonstrations.

NASA's educational services, offered primarily through established educational agencies, helped teachers and students keep abreast of developments in the space sciences and provided information to community groups and agencies offering general education courses and lectures to adults.

The Agency also continued to employ educational publications, motion pictures, radio and television to lessen the gap between rapid U.S. progress in aerospace science and technology and adequate dissemination of information on these advances to educators, students, and the general public.

Youth Science Congresses

NASA and the National Science Teachers Association jointly sponsored several youth congresses during the last six months of 1963. The congresses brought 300 high school science students, selected on the basis of their original research, to the Agency's headquarters and its various centers.

Participating in an "advanced science seminar," these gifted students presented their research papers, discussed them with one another, and with NASA scientists serving as advisors.

The National Science Teachers Association has considered these congresses to be successful enough to warrant initiating a program to conduct similar ones in many cities and counties on a self-supporting local basis.

Adult Education Pilot Project

An adult education project in Rhode Island was aimed at determing if lecture courses providing a general educational background in NASA-sponsored developments in space science and technology might be conducted independently of the resources of one of the Agency's research centers. Numerous courses of this type in the past have depended on the resources available from nearby NASA installations.

The Rhode Island project, undertaken by NASA and the Rhode Island State Education Department through the public schools at Warren, successfully used the resources of neighboring industry and a university for its program.

Guidelines from these lecture courses—with an average enrollment of 100—will be made available to adult education organizations and NASA centers to benefit similar adult education programs.

Summer Courses and Workshops

During the summer of 1963 NASA assisted 178 colleges and universities in planning space science courses and providing workshops for about 6,000 preservice and inservice teachers. Such courses offer a virtually unique opportunity for elementary and secondary school teachers to obtain a broad understanding of the Nation's space program.

The courses ranged from those in Louisiana, Maine, and South Dakota supported on a statewide basis with the cooperation of state education departments and higher education systems to others in New York assisted on a local and individual basis. Assistance by NASA included help in organizing courses, providing lecturers and discussion leaders, arranging field trips to Agency installations, and the provision of instructional materials.

Materials of Instruction

Four current projects involve preparing materials of instruction to help schools introduce the space sciences into their programs. These instructional materials, including units of work and course syllabi, are scheduled to be available to teachers before the workshops of the summer of 1964 are held.

Spacemobiles

In the last 6 months of 1963, 15 spacemobile lecture-demonstration teams provided information on NASA's space science and exploration programs to over a million children and adults in schools, teacher training institutions, and civic groups throughout the United States.

Spacemobile lecturers also made 48 TV appearances and 18 radio broadcasts. Special activities included participation in: the Centennial of the Emancipation Proclamation in Chicago and Indianapolis; the Nuclear Space-O-Rama in Idaho Falls, Idaho; the Houston International Trade Fair; the Oklahoma State Fair; the Billings, Mont., Space-O-Rama; Space Science Achievement Week in Orlando, Fla.; the annual meeting of the Georgia Science teachers; and the Space Research Exposition in Detroit.

In some States spacemobiles were so solidly booked at the beginning of the report period that requests could not be filled for a year. To help meet these overwhelming demands, a number of additional spacemobile staff members were carefully chosen from the teaching profession in the fall of 1963 and given intensive training in preparation for a limited enlargement of this popular program.

Spacemobiles continued to explain this country's space program to teachers and students in other countries. Units in India cooperated with the Indian National Committee for Space Research; in France, Luxembourg, and the Federal Republic of Germany with the Preparatory Committee for European Space Research; in Brazil with the Brazilian Space Agency; in Mexico with the Commission of Communications and Meteorology; in Venezuela with the Humboldt Planetarium; in Surinam, South America with the Aeronautical and Space Exposition Foundation; and in the African nations of Nigeria, Ghana, Liberia, Malagasy Republic, Ruanda-Urundi, and the Republic of the Congo with the U.S. Information Agency.

Educational Publications[1]

During the report period, NASA issued the following publications:

1. "America in Space"—a pictorial review of NASA's accomplishments since it was established October 1, 1958.
2. "The Search for Extraterrestrial Life"—a description of techniques using robot devices to determine if life exists on other planets.
3. "The Triumph of L. Gordon Cooper, Jr., and the Faith 7"—an illustrated booklet describing the 22-orbit Project Mercury flight of May 15–16, 1963.
4. "NASA Facts, Syncom"—a nontechnical description of experiments with communications system using satellite in synchronous orbit.
5. "Historical Origins of the National Aeronautics and Space Administration"—an account of the establishment and early activities of NASA.

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[1] Copies of these publications are available upon request from the Office of Educational Programs and Services, Educational Publications Branch, National Aeronautics and Space Administration, Washington, D.C., 20546.

6. "NASA Educational Opportunities"—a publication which enumerates opportunities for undergraduate and graduate studies and other training available for NASA employees.
7. "Meteorological Satellites"—a booklet describing the TIROS and Nimbus weather satellites by Dr. Morris Tepper, Director of NASA's Meteorological Systems.
8. "Space Science and the Physics Teacher"—a compilation of papers presented by NASA scientists at the summer meeting of the American Association of Physics Teachers at the University of Maine.

Reprints from periodicals included: "We Know So Shamefully Little About the Moon" by Howard Simons of the *Washington Post —Times Herald*; "Mercury-Atlas 9"—sketches and paintings by eight leading American artists of Astronaut Cooper's flight on May 15-16, as reproduced in *Art in America*; and "Strange New World" from *Occupational Outlook Quarterly* which describes employment opportunities with NASA.

In addition, updated editions were published of the three *Aeronautics and Space Bibliographies* for elementary, secondary, and adult educational use.

Motion Pictures[2]

Three motion pictures in color and sound were released by NASA during the report period:

1. *America in Space—the First Five Years* (13½ minutes) a documentary of NASA's principal achievements since it was established on October 1, 1958.
2. *Flight of Faith 7* (28½ minutes) a presentation covering the 22-orbit flight of Astronaut Cooper.
3. *Project Apollo—Manned Flight to the Moon* (13 minutes) an animated film on NASA's program culminating in manned lunar exploration.

Motion Picture Awards—The film on NASA's Project Mercury manned space flights—*Mastery of Space*—won a gold medal and received the special scientific award at the First International Aeronautics Film Festival, Deauville, France. *Ariel* (the first international—United Kingdom-United States—satellite, which

[2] Available to the public without charge other than return mailing and insurance costs. Requests should be addressed to the National Aeronautics and Space Administration, Office of Educational Programs and Services, Educational Audio-Visual Branch, Washington, D.C., 20546.

studied the upper atmosphere) was awarded a diploma of participation at the International Exhibition of Documentary Films, Venice, Italy, and a certificate of presentation at the Edinburgh, Scotland film festival. *Project Apollo—Manned Flight to the Moon* received a certificate of presentation at the Edinburgh festival.

Film Depository Services—By the end of the report period, the Office of Educational Programs and Services had catalogued and stored 5,631,640 feet of motion picture film. Approximately 50,000 feet of film was made available to producers of educational and documentary movies and telecasts.

Radio and Television

Over 2,000 radio stations received audio tapes of a 5-minute weekly educational series "Space Story". The tapes included interviews, sound effects, and other audio material covering scientific and technical aspects of space exploration.

"Space: Man's Great Adventure" TV documentaries will be released to the networks beginning in the Spring of 1964. These telecasts, for high school and adult audiences, will include detailed information on major space projects.

Approximately 2,000 radio stations, 150 TV stations, and a large number of closed-circuit systems were provided audio-visual materials on space science for school and home audiences.

Exhibits

NASA's domestic exhibits program during the last 6 months of 1963 was highlighted by preparations of the Agency and the Department of Defense for joint participation in the New York World's Fair opening April 22, 1964.

A U.S. Space Park, sponsored by NASA, the Defense Department and the Fair, will feature the most outstanding collection of full-scale NASA and Air Force rockets and spacecraft ever assembled outside of Cape Kennedy. Included will be a full-scale model (53 high and 33 feet in diameter) of the aft end of the Saturn V rocket for the manned lunar exploration of Project Apollo and a Titan II-Gemini launch vehicle and spacecraft towering 110 feet over the 2-acre exhibit. The Titan booster will stand with the two-man Gemini spacecraft mated on top just as if it were on the launching pad at Cape Kennedy.

The Titan II rocket will be surrounded by full-scale models of the Project Apollo command and service modules, the lunar excursion module, the Project Gemini spacecraft, and the Project Mercury capsule which carried Astronaut Scott Carpenter on his three-orbital flight of May 24, 1962.

Other full-scale exhibits in the Space Park will be the Atlas-Mercury and Thor-Delta launch vehicles, an X–15 rocket-powered research spacecraft, and the Atlas-Agena space vehicle. (Atlas-Mercury was used to orbit the Nation's astronauts during the highly successful Project Mercury; Thor-Delta orbited the communications satellites Telstar and Relay, the TIROS meteorological satellites, and the Explorer geophysical satellites. Atlas-Agena launched the Mariner II spacecraft which flew within 21,594 miles of Venus in December 1962.)

The Space Park grounds and utilities for the NASA-Defense Department exhibits are provided without cost to the Government and no separate admission will be charged to see them.

A nationwide tour of Gordon Cooper's spacecraft to the 50 State capitals opened in Oklahoma late in September. By November more than 250,000 people in five States were estimated to have seen this capsule used in the final manned orbital space flight of Project Mercury in May 1963.

Among the other numerous domestic exhibits of the July-December 1963 report period were showings at the Boulder (Colo.) County Fair; New York State Exposition at Syracuse; Boy Scouts of America, Champaign, Ill.; Tanana Valley Fair, Fairbanks, Alaska; Aerospace Institute for Teachers, Tallahassee, Fla.; "Salute to Space Science Achievements," Orlando, Fla.; National Convention on Military Electronics, Washington, D.C.; Collier Trophy Award Luncheon, Washington, D.C.; Kiwanis Kid's Day Space Show, Cincinnati, Ohio; Los Angeles (Calif.) International Airport dedication; Space Show, Pacific Missile Range, Point Mugu, Calif.; St. Louis Planetarium, St. Louis, Mo.; and the 68th Annual Congress of American Industry, New York.

Almost 13,687,000 in this country saw exhibits on the Nation's space program during this period.

Exhibits Overseas

NASA's exhibits, and exhibits of the Agency sponsored by the U.S. Information Agency (USIA), were shown in various parts of the world from July through December of this year.

The space capsule of Astronaut Schirra was exhibited at the International Boy Scout Jamboree in Marathon, Greece, in August;

and later in the year, under USIA auspices, at Athens and Thessalonika, Greece; Tunis; Amsterdam; and Tokyo. A total of about 940,000 viewed these major exhibits.

Scientific and Technical Information

During the last 6 months of 1963, NASA's scientific and technical information activities and services increased markedly. The substantial increase was primarily a reflection of the Agency's rapidly expanding research and development work; a mounting flow of knowledge from the laboratories and workshops of NASA aerospace contractors; and a progressively broadening interest of science and industry in these research results coming from NASA and its contractors.

This progress report outlines some of the highlights.

Selective Dissemination of Information

NASA's Selective Dissemination of Information (SDI) program provides its scientists and engineers with speedy announcements of new reports of interest to them. This computerized method, initiated during the first half of 1963 (Ninth Semiannual Report, p. 152), is undergoing developmental tests by 500 volunteer employees of the Agency.

In the SDI program, a computer compares each man's "interest profile" (subject terms and phrases related to his work and interests) with subject indexes of reports to be annotated in current issues of NASA's announcement journal *Scientific and Technical Aerospace Reports* (*STAR*). An abstract of the selected report is mailed directly to the participant when his interest profile matches the subject of the document. Mechanized systems allow delivery even before abstracts are available in the journal.

This SDI system, in addition to offering a prompt announcement service, provides a convenient way to request a copy of the report abstracted. To quickly modify a man's profile when his interests or activities change, each abstract is accompanied by a response card on which may be indicated an order for a copy of the report, a lack of interest in the report, or comments on the report. Computer analysis of the response cards then permits a study of the effectiveness of the program and supplies data for improving the overall program and for refining and updating the individual's interest profile.

Several machine techniques for comparing interest profiles and subject indexes are being tested, and the most effective form of interest profile is being determined. Fully developed, the program will be adaptable to decentralized operation by libraries at NASA centers and by the Agency's principal contractors, and promises to become one of the world's most advanced systems for disseminating scientific information.

Translations

During 1963 NASA expanded its program to produce translations of foreign scientific literature in the aerospace field. Translations of widespread interest were prepared, distributed within the Agency and to its contractors, and also sold to the public through the Office of Technical Services, U.S. Department of Commerce, Washington, D.C., 20230. A wider selection of foreign scientific journals was regularly scanned, and English abstracts of articles were prepared for either the Agency's abstract journal *Scientific and Technical Aerospace Reports* or the *International Aerospace Abstracts,* prepared by the American Institute of Aeronautics and Astronautics with NASA support.

Among translations issued during the last 6 months were those of four books: *Meteorological Investigations with Rockets and Satellites* by K. Ya. Kondrat'yev; *Problems of Space Biology,* vol. 1, by N. M. Sisakyan; *Electron and Ion Emission* by L. N. Dobretsov, all from the U.S.S.R.; and *Tungsten and Molybdenum* by C. Agte and J. Vacek, from Czechoslovakia.

Exchanging Information with Other Government Agencies

In order to acquire technical information for use in the Nation's space program, NASA has developed a comprehensive system for scanning research and development reports of other Government agencies and their contractors. Technical reports and publications collected by this method are distributed to the Agency's laboratories and its contractors.

Technical information generated within NASA is similarly made available to other agencies, assuring the transfer of scientific ideas through a continuing large-scale interchange of information and at the same time guarding against duplication in areas of common interest.

Announcement Services

NASA's *Scientific and Technical Aerospace Reports* basic announcement journal, in 1963, announced more than 13,500 items from worldwide report literature as compared to 7,500 items in 1962. *International Aerospace Abstracts*—published by the American Institute of Aeronautics and Astronautics and supported by NASA—announced more than 16,000 items in the world's journal and book literature for the same year as compared to the 12,000 of 1962.

Computer Retrieval System

Magnetic computer tapes were distributed for direct use by principal organizations in NASA's programs through the mechanized information storage and retrieval system being operated by the Agency. Up-dated copies of tapes containing documentation data were distributed monthly to a growing number of recipients. Included was retrieval data on reports and journal articles on aerospace science and technology announced in either *Scientific and Technical Aerospace Reports* or *International Aerospace Abstracts.*

The tapes—distributed at the same time or before these journals were mailed—offered prompt access to information contained in more than 50,000 documents and assured that NASA centers and major contractors will be able to perform many valuable search tasks locally.

This magnetic computer tape program, still in a developmental stage, promises at least three major benefits: results locally achieved by high-speed computer print-out; more precise and efficient retrieval due to greater depth in indexing; and freedom from delays and "communications-caused" misunderstandings likely in using a single centralized source.

Technical Publications

An expansion of NASA's research and development work before 1963 was reflected in a 30-percent increase in the number of scientific and technical reports, including a new series of formal contractor reports, published during the second half of 1963. More than 400 documents were released during the period, ranging from abstruse reports on narrowly limited studies to project summaries and symposia proceedings of several hundred pages.

Work also continued on a number of forthcoming scientific and technical books and monographs, such as a sourcebook on the space sciences, a reference work on advanced bearing technology, a summary of the results of the X-15 research airplane program, and a projected series of monographs on the research findings of NASA's scientific satellites.

Historical Program

In October the historical staff became part of NASA's Office of Technology Utilization and Policy Planning, which released three reports during the last 6 months of 1963. These were: *Historical Origins of NASA*,[3] an illustrated pamphlet published by the Office of Educational Programs and Services; the *First Five Years of NASA—A Concise Chronology*,[3] issued to mark the Agency's fifth anniversary; and *Project Mercury—A Chronolgy (SP-4001)*,[3] issued by the Office of Scientific and Technical Information.

A "History of Rocket Technology," edited by the Agency's historian, was published as the fall 1963 issue of *Technology and Culture*, quarterly of the Society for History of Technology.

The historical staff also participated late in 1963 in the Government-wide oral history and documentary program supporting the establishment of the John F. Kennedy Memorial Library at Harvard University. In addition, it cooperated with the history committees of the National Space Club (sponsor of the Robert H. Goddard Historical Essay Competition), the International Academy of Astronautics, and the American Institute of Aeronautics and Astronautics.

To provide guidance in instituting comprehensive records and histories of space exploration, a NASA Historical Advisory Committee of nationally recognized historians was established in December.

[3] *Historical Origins of NASA* and *Project Mercury—A Chronology, SP-4001* are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, for 15 cents and $1.50, respectively; copies of the *First Five Years of NASA—A Concise Chronology* are available from the NASA Historian, Office of Technology Utilization and Policy Planning, National Aeronautics and Space Administration, Washington, D.C., 20546.

Personnel, Management, Procurement, and Support Functions

To provide the necessary support for its increasingly complex missions, NASA continued seeking means of improving its nontechnical activities. The Agency made further progress in recruiting competent personnel for both technical and nontechnical functions. It also made further improvements in its organizational structure, thus assuring increasingly effective management of its programs and resources. And it continued to conduct its financial affairs in the soundest possible manner and to improve its procurement techniques and procedures.

Personnel

In the personnel field, NASA sought further means of improving employee effectiveness, continued with its manpower study of scientists and engineers, studied the possible application of a new method for selecting scientists, and took further steps to improve employee-management cooperation. While the Agency continued to hire new scientists and engineers, its rate of growth during this period was lower than that during the preceding comparable period. Key personnel changes were effected to improve management, and well deserved awards were made to individuals and groups for their contributions to the Nation's space program.

Employee Improvement

A new 3-day Management Seminar was developed to train NASA personnel engaged in facility construction management in the objectives, operations, and benefits of network planning techniques. The seminar is expected to highlight application of NASA-PERT to facility construction projects during their total life. In particular, emphasis is to be placed on the use of the system during the preliminary planning and early design phase and on the relationship with Research and Development projects. Approximately 200 employees have attended the Seminar since its inception.

An Agency-wide Supervisory Training Program was developed in cooperation with the Civil Service Commission. One pilot course was conducted at Headquarters, and additional courses were scheduled at various Centers. In addition, investigation was being made into the application of programmed learning in this area.

A Financial Management Seminar was designed to provide program and project managers with a broad understanding of the NASA financial management structure and its relationship to program and project management.

Continued emphasis was given to established seminars and training programs; these included the NASA-PERT and Companion Cost System Seminar, the Conflict of Interest and Standards of Conduct Training Program, Procurement Management Seminar, Quality Assurance Training Program, Graduate Study Program, Cooperative Educational Program, and the Management Intern Program.

NASA Scientist and Engineer Manpower Study

On July 1, 1963, about 58,600 scientists and engineers were employed in NASA's national space program. Of these, 10,978 were Government employees working inside NASA. About 47,622 were employed on NASA programs under contracts and grants. These 58,600 amounted to 4.03 percent of the estimated 1.455 million scientists and engineers in the Nation's work force.

As of December 31, 1963, approximately 64,000 scientists and engineers were working on NASA's national space program; this total represents about 4.3 percent of the national requirements for scientists and engineers.

Manpower projections for the remainder of the decade show that NASA's program is not expected to use higher than 5.8 percent of the national requirements for scientists and engineers.

The scientists and engineers engaged in the research and development part of NASA's program totaled about 47,850 on July 1, 1963. This was 8.7 percent of the Nation's 550,000 scientists and engineers working primarily on research and development.

NASA's training grants were supporting nearly one thousand full-time graduate students for advanced training in fields related to aerospace needs. Over 2,000 NASA scientists and engineers were taking at least 1 graduate course in fields related to the Agency's needs.

From these statistics, the following conclusion may be drawn:

1. Scientists and engineers working on NASA's national program represent only a small portion of the Nation's requirements for scientists and engineers.
2. A larger, but still small, percentage of the Nation's research and development scientists and engineers are working on NASA's program.
3. The growth of NASA's program has thus far been accomplished without any apparent harm to other research and development programs or activities.
4. NASA is making a major contribution to increasing the Nation's resources of highly trained scientists and engineers.

NASA To Use New Selection Method

For approximately 4 years, with NASA support, the University of Utah has been conducting research on means of improving selection of scientists and engineers. As a result of the favorable research findings obtained on 1,400 scientists to date, NASA intends to start using a Biographical Inventory as another source of information to supplement its selection procedures.

In work that was completed three different forms of the Biographical Inventory were constructed and administered at three different NASA research installations; the objective was to predict success in science as measured by supervisor ratings on creativity, quality of work output, and others. In studies to double check the results of earlier samples, at least moderate to very good results have been obtained on large samples in predicting success as measured by these devices.

There is evidence that the biographical scores from the keys developed through this research have a high degree of stability. The research also demonstrated that the same keyed scores that correlate with creativity and other measures of success in science for mature scientists will satisfactorily predict later scientific research achievement for high school and college students.

In summary, all of the results obtained to date indicate that biographical information could make an important contribution to the identification of creative scientific talent in NASA selection processes.

Employee-Management Cooperation

During the period, NASA took further steps to implement Executive Order 10988 on employee-management cooperation in the federal service. These steps included the following actions:

a. Exclusive recognition was granted to one local labor organization at each of two NASA installations (Goddard and Langley).
b. Arbitration of the appropriate unit question at one NASA installation (Marshall) took place in December. (The arbitrator's advisory decision is expected in late February 1964.)
c. Policies and procedures were formulated to implement (1) the President's Standards of Conduct for Employee Organizations and Code of Fair Labor Practices; (2) Voluntary union dues withholding; and (3) rules for nomination of arbitrators.

Recruitment of Personnel

As stated earlier, NASA's rate of growth in scientists, engineers, and mathematicians decreased significantly during this period as compared with the growth experienced during fiscal year 1963. The total scientists, engineers, and mathematicians on board on June 30, 1963, was 10,978. On December 31, 1963, the total was 11,463. However, it was necessary to recruit 879 qualified persons during this 6 months because, in addition to the increase of 485, in total positions, 394 individuals who left NASA had to be replaced.

The total NASA personnel complement in all categories went from 29,934 to 30,069 during this period. On December 31, 1963, the total complement was distributed as follows:

Physical scientists, life scientists, and engineers in aerospace technology and in related supervisory and management positions: 11,034.

Engineers, mathematicians, and other technical professionals supporting the above group: 429.

Scientific and engineering assistants and technicians such as draftsmen, designers, computer specialists, and illustrators: 3,637.

Professional, administrative, and management positions in legal, procurement, personnel, finance, technical information, education, and related specialized areas: 3,064.

Clerical and administrative positions: 5,133.

Skilled trades and crafts employees and related skilled, semi-skilled, and unskilled laborers: 6,772.

Included in the NASA civilian staff on December 31, 1963, were 100 noncitizen scientists. In addition, 239 military personnel were serving on reimbursable detail from the armed services.

This manpower data does not reflect the 4,167 employees of the Jet Propulsion Laboratory, Pasadena, Calif., which is operated for NASA under contract with the California Institute of Technology.

Geographical distribution of personnel by installation on June 30, 1963, and December 31, 1963, was:

Organization:	*June 30, 1963*	*Dec. 31, 1963*
Ames Research Center	2,116	2,166
Flight Research Center	616	618
Goddard Space Flight Center	3,487	3,443
Langley Research Center	4,220	4,234
Lewis Research Center	4,697	4,760
Marshall Space Flight Center	7,332	7,227
Manned Spacecraft Center	3,345	3,364
Wallops Station	493	502
Western Operations Office	308	318
Headquarters	2,001	2,017
AEC/NASA Space Nuclear Propulsion Office	96	102
North Eastern Office	25	30
Pacific Launch Operations Office	17	19
John F. Kennedy Space Center (formerly Launch Operations Center)	1,181	1,269
Total	29,934	30,069

Key Executive Personnel Changes

During the period, a number of key personnel changes took place within NASA. Except for the resignations and retirements, these changes were made to provide for improved management of the space program.

Key Appointments.—On July 12, 1963, Earl D. Hilburn was appointed as Deputy Associate Administrator in charge of field operations for all nonmanned space flight centers. On November 1, 1963, he was reassigned as Deputy Associate Administrator for Industry Affairs. He came to NASA from the position of Vice-President and General Manager, Electronics Division, Curtiss-Wright Corporation, Woodridge, N.J.

On September 3, 1963, George E. Mueller was appointed as Deputy Associate Administrator for Manned Space Flight. On November 1, he was redesignated as Associate Administrator for Manned Space Flight. Dr. Mueller came from the position of Vice President for Research and Development, Space Technology Laboratories, Inc., Redondo Beach, Calif.

On October 14, 1963, Edward Z. Gray was appointed as Director of Advanced Studies in the Office of Manned Space Flight; on November 1, he was reassigned to the position of Director, Advanced Manned Missions Program in that office. Mr. Gray came to NASA from the Boeing Co., Seattle, Wash., where he had served as Program Development Manager for Advanced Space Systems in their Aero-Space Division.

On November 1, 1963, Robert B. Young was appointed Director, Industry Operations at the NASA Marshall Space Flight Center. Mr. Young came from the position of Vice President and General Manager for all plants of the Aerojet General Corp. within the Sacramento area.

On November 21, 1963, Donald K. Slayton was appointed as Assistant Director for Flight Crew Operations, NASA Manned Spacecraft Center, Houston, Tex. Mr. Slayton had formerly served as a member of the original team of Astronauts for Project Mercury, having been detailed to this team, with rank of Major, by the U.S. Air Force.

Reassignments.—Reassignments of key personnel within NASA were made as follows:

Homer E. Newell was reassigned from Director, Office of Space Sciences (from November 1, 1961) to Associate Administrator for Space Science and Applications.

Raymond L. Bisplinghoff was reassigned from Director, Office of Advanced Research and Technology (from August 1, 1962), to Associate Administrator for Advanced Research and Technology.

George L. Simpson, who had been serving as Assistant Administrator for Technology Utilization and Policy Planning was also designated as Assistant Deputy Administrator. (Dr. Simpson had initially been appointed as Assistant Administrator for Public Affairs on September 1, 1962.)

Richard L. Callaghan, who had served as Special Assistant to the Administrator from July 30, 1962, was appointed Assistant Administrator for Legislative Affairs.

Walter L. Lingle was appointed as Deputy Associate Administrator. He had been initially appointed as Assistant to the

Administrator on June 25, 1962, and reassigned as Assistant Administrator for Management Development in August 1962. From April 23, 1963, until November 1, 1963, he had served both as Assistant Administrator for Management Development and Deputy Associate Administrator for Industry Affairs.

Julian W. Scheer was reassigned from Deputy Assistant Administrator for Public Affairs to Deputy Assistant Administrator for Technology Utilization and Policy Planning, on April 26, 1963, and to his present position as Assistant Administrator for Public Affairs as of November 1, 1963.

DeMarquis D. Wyatt was reassigned from Director, Office of Programs (from November 1, 1961), to Deputy Associate Administrator for Programing.

John D. Young was reassigned from Director of Administration (from June 23, 1963) to Deputy Associate Administrator for Administration.

On November 1, 1963, Hermann K. Weidner, the former Deputy Director of the Propulsion and Vehicle Engineering Division of the Marshall Space Flight Center, was appointed Director of Research and Development Operations for the center, in the implementation of a major reorganization of Marshall on that date.

On December 1, 1963, Joseph M. Shea, who had served as Deputy Director, Office of Manned Space Flight (for Systems), was appointed as Manager, Apollo Spacecraft Program Office at the NASA Manned Spacecraft Center, Houston, Tex.

On December 8, 1963, Walter D. Sohier was appointed as General Counsel, succeeding Mr. John A. Johnson (see terminations, below). Mr. Sohier had served as Assistant General Counsel from November 1958, and as Deputy General Counsel from November 1, 1961.

Resignations and Other Terminations.—The following resignations or retirements occurred within this period:

D. Brainerd Holmes, who had served as Director, Office of Manned Space Flight, from November 1, 1961, resigned effective September 17.

Abraham Hyatt, who had served as Director, Office of Plans and Program Evaluation from December 1, 1960, resigned effective October 31. Previously, he had served as Assistant Director for Propulsion in the Office of Space Flight Development (from October 1958), and as Deputy Director, Office of Launch Vehicle Programs (from February 1960).

On November 28, 1963, Robert H. Charles resigned from the position of Special Assistant to the Administrator, to which he had been appointed June 14.

John A. Johnson resigned from the position of General Counsel effective December 7, 1963. He had served in that capacity from October 20, 1958 when he had joined the staff of NASA by transfer from the position of General Counsel, Department of the Air Force.

Addison M. Rothrock retired from the position of Director, Policy Planning Staff, effective December 30, 1963. He had joined the former National Advisory Committee for Aeronautics, in its Langley Laboratory in 1926, and had headed the fuel research programs at the NACA's Lewis Laboratory from 1941 to 1945, where he then served as Chief of Research from 1945 to 1947. From 1947 to 1958 Mr. Rothrock had served as Assistant Director for Research (Propulsion) in the NACA Headquarters, and from 1958 to October 31, 1963 had served as Senior Scientist for Propulsion and later Associate Director, Office of Plans and Program Evaluation. He was named Director, Policy Planning Staff on November 1, 1963.

NASA Awards and Honors

During the period, NASA gave special recognition to certain individuals and groups for their accomplishments and contributions to the Nation's space program.

NASA Medal for Outstanding Leadership.—For outstanding leadership, NASA made the following awards:

D. Brainerd Holmes, Office of Manned Space Flight, Headquarters: For his outstanding leadership of the manned space flight program during the formative period of Project Apollo and for his imaginative and energetic leadership in forging a manned space flight organization dedicated to advancing the United States toward its goal of preeminence in space.

Charles J. Donlan, Langley Research Center: For outstanding leadership in connection with the establishment of organizational and technical concepts for Project Mercury including astronaut selection and training; for developing the original technical concepts for Project Apollo and for continued contributions to manned space flight technology through the planning and direction of programs of advanced research that effectively support current and future flight project development.

Walter Haeussermann, Marshall Space Flight Center: For outstanding leadership as a scientist, engineer, and director of a large research organization responsible for developing guidance, control, onboard measuring, telemetering tracking and related systems, assemblies, and components for launch vehicles and space.

William A. Mrazek, Marshall Space Flight Center: For outstanding leadership in extending the frontiers of aerospace knowledge through exceptionally adroit management and direction of research and development of space vehicles in the fields of structures, mechanics, propulsion, materials, and related engineering.

John A. Johnson, Headquarters, NASA: In recognition of his outstanding leadership and dedicated service in creating and maintaining a highly effective legal organization during NASA's formative years, and for significant contribution to patent law, to the law of outer space, and to the overall policy and progress of the U.S. space program.

NASA Medal for Exceptional Scientific Achievement.—This medal was presented to the following individuals:

Dean R. Chapman, Ames Research Center: For significant contributions to the lunar exploration program through research and investigations on the origin and properties of tektites and for research on atmospheric-entry physics and space mechanics.

Ernst D. Geissler, Marshall Space Flight Center: For exceptional scientific achievement and invaluable individual accomplishments in the aerospace technological programs of the National Aeronautics and Space Administration, especially for his significant contributions to the Mercury-Redstone, Saturn I, Saturn V, and Nova.

Don D. Cadle, Headquarters: For his vision, leadership, and drive in the creation and implementation of the concept, policies, and practices leading to centralized planning and management of NASA resources during a critical period when the NASA budget expanded fivefold.

Abraham Hyatt, Headquarters: For his leadership and personal participation in the long-range planning of the National Space Program as a vital element of U.S. technological strength and preeminence.

John A. Houbolt, Langley Research Center: For his foresight, perseverance, and incisive theoretical analysis of the concept of Lunar Orbit Rendezvous, revealing the important engineering and economic advantages that have led to its adoption as a central element in the United States Manned Lunar Exploration Program.

NASA Group Achievement Award.—This award was presented to the Recruiting and Examining Branch, Personnel Division, Office of Administration, Headquarters, for significant contribution to the agencywide recruiting effort that resulted in the employment of 3,509 scientists and engineers during the 12-month period ending June 30, 1963.

Certificate of Appreciation.—Certificates of appreciation were presented to the following individuals:

Addison M. Rothrock, Headquarters: For his outstanding contributions over a period of more than 20 years in aeronautical research, especially in propulsion and in rocket technology, and for his contributions toward better public understanding of the problems and goals of space flight.

Carroll A. Towne, Headquarters: For significant contributions made to the National Aeronautics and Space Administration in planning and developing the Agency's community development program.

The Inventions and Contributions Board

During the period, the Inventions and Contributions Board continued to evaluate scientific and technical contributions made by any person, either NASA employees or contractor personnel. The Board continued to examine requests for waiver of patent rights and make appropriate recommendations.

Contributions Awards

NASA's Inventions and Contributions Board evaluates for possible monetary award the scientific and technical contributions made by any person (section 306, Space Act of 1958). During the reporting period, the Board received 1,493 communications and evaluated 796 contributions. From such evaluations, the Agency made five awards—three to NASA employees and two to contractor employees. Also, under the Incentive Awards Act of 1954, the Board made 59 monetary awards for inventions of NASA employees. (See app. D for Membership of the Inventions and Contributions Board, app. E for list of awards.)

Patent Waiver Petitions Granted and Denied

The Inventions and Contributions Board also recommended that the petitions for 29 waivers of patent rights be granted and 12 denied. Of these cases, the Administrator approved 9 waivers of patent rights to be granted and 4 to be denied. Action on the other cases was still pending. A list of waivers granted and denied is included as appendix F. In addition, appendix G lists other waivers recommended for grant or denial by the Inventions and Contributions Board during this period.

Organizational Improvements

Changes in the scope and character of NASA's programs led to the following major organizational and managerial improvements which became effective on November 1, 1963.

Program and Field Center Management Consolidated

Authority and responsibility for planning and managing NASA's major programs and for directing the overall management of the field centers executing these programs were consolidated and assigned to three headquarters officials reporting to NASA's "general manager," the Associate Administrator. Previously, Center Directors received direction for project management from one or more Headquarters Program Director(s), while direction for general institutional operation of the Centers came from the Associate Administrator. Under the realinement of functions, each Center Director has only one supervisor at Headquarters; both technical and institutional management activities are integrated at a single point below the Associate Administrator. Relieving the Associate Administrator of direct responsibility for overall management of Centers leaves him more time to devote to interagency groups and agencywide policies and problems.

Officials responsible for consolidated management and direction of NASA's major programs are:

An *Associate Administrator for Manned Space Flight,* who directs this program and is also responsible for overall management of the three Centers primarily engaged in manned space flight activities—Marshall Space Flight Center, Manned Spacecraft Center, and John F. Kennedy Space Center.

An *Associate Administrator for Space Science and Applications,* who is responsible for scientific explorations of space, as well as communications, meteorological, and related peaceful

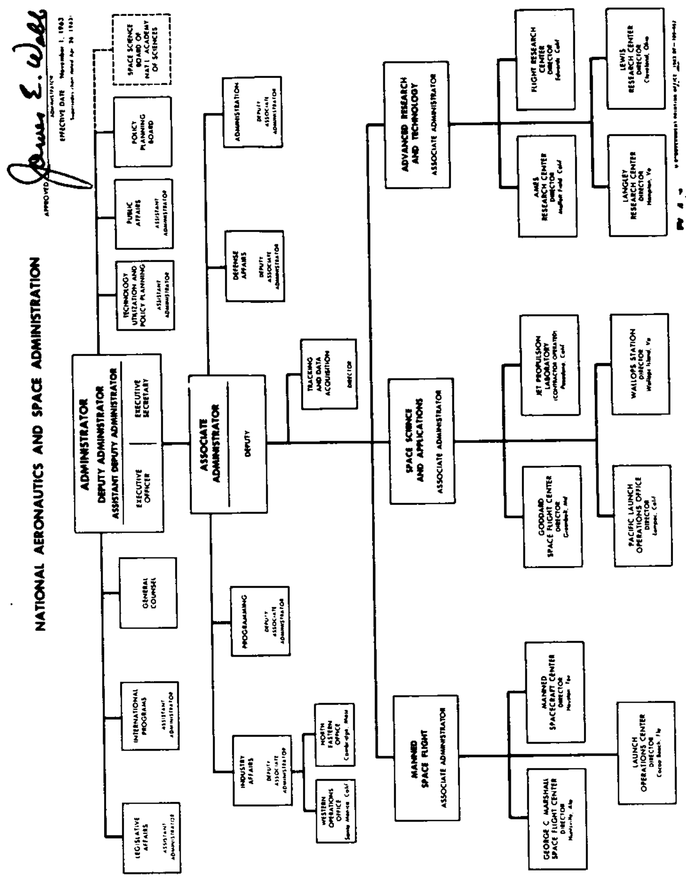

Figure 10–1. NASA organization chart (November 1, 1963.)

applications. Space Science and Applications were combined under one Associate Administrator since these programs employ essentially the same launch systems and use the same Centers. Field installations under this official's overall management are Goddard Space Flight Center, Wallops Station, Pacific Launch Operations Office, and the contractor-operated Jet Propulsion Laboratory.

An *Associate Administrator for Advanced Research and Technology,* who is responsible for NASA's program to provide technical knowledge essential for future aeronautical and space vehicle design. In addition, this official coordinates the Agency's total research program to assure its overall adequacy and to avoid unnecessary duplication. Installations under his overall management are Ames Research Center, Langley Research Center, Lewis Research Center, and Flight Research Center.

The *Director of the Office of Tracking and Data Acquisition* continues to have responsibility for providing and integrating tracking and data acquisition services and facilities within NASA and for relationships in these matters with agencies of the Department of Defense.

Other Headquarters Organizational Elements Realigned

An *Assistant Deputy Administrator* was appointed to relieve the Administrator and Deputy Administrator of certain specific responsibilities and to allow them more time for overall policy matters and relationships with other agencies and Congress.

A *Deputy Associate Administrator* was appointed to assist the Associate Administrator, primarily on organizational and managerial matters of concern to general management.

A *Policy Planning Board* was established, consisting of senior Headquarters and Center officials, to advise top management on policies covering all NASA activities.

The *Assistant Administrator for Technology Utilization and Policy Planning* provides specialized assistance to the Policy Planning Board. In addition, this Assistant Administrator retains responsibility for promoting widespread utilization of technological innovations emanating from NASA's research and development activities, for directing a program for the dissemination of scientific and technical information, and for advising the Administrator on certain relationships with universities. He also supervises the work of the Policy Planning Division.

An *Assistant Administrator for Public Affairs* was appointed, reporting directly to the Administrator. The public information, educational program, and related public affairs activities were placed under the direction of this official.

The responsibilities of the *Deputy Associate Administrator for Industry Affairs* were expanded to include monitoring of NASA's rapidly growing construction program, obtaining sound reliability and quality assurance programs, and providing support and services to the Inventions and Contributions Board.

A *Management Committee* was established, composed of all officials reporting directly to the Associate Administrator. This committee is to assist and advise on agencywide management systems and on managerial, organizational, and operational problems involving more than one NASA organizational element.

Financial Management

During the 6 months ended December 31, NASA took specific action to improve its financial management:

The Agency made the initial installation of an accrual system of accounting on July 1, 1963. This system is to provide essential and timely data on costs as well as the obligation and expenditure information previously available. The system was designed to produce the cost data needed by various levels of NASA management for effective control of operations and measurement of accomplishments.

The Agency furthered its efforts to work closely with contractors in the integration of their accounting systems with NASA's. This will minimize the duplication of accounting, recordkeeping, and reporting effort.

A procedure was developed to provide semiannual reports relating to the approximately $200 million of NASA-owned industrial facilities and materials in the hands of contractors. Such reports should promote efficient management and use of the property.

NASA installed an Agency-wide system of manpower utilization reporting to provide for a continuing monthly appraisal of program execution against objectives, in terms of man-months of effort.

A mechanized Agency-wide system was installed to integrate the reporting of financial and statistical data on the status of contracts and grants. Incidental management benefits are derived from the introduction of the same mechanized input into the Headquarters Data Bank as a common source for other Headquarters management reports.

For the fiscal year 1965 program, table 1 shows the planned levels of effort in research, development, operation, and construction of facilities.

Financial Report, December 31, 1963

Table 2 shows funds obligated and disbursed during the first six months of fiscal year 1964. Appended is a summary by appropriation showing current availability, obligations against this availability, and unobligated balances as of December 31, 1963.

TABLE 1.—*NASA budget estimates, fiscal year 1965*
[In thousands]

Administrative Operations	$641,000
Research and Development:	
Gemini	308,400
Apollo	2,677,500
Advanced missions	26,000
Geophysics and astronomy	190,200
Lunar and planetary exploration	300,400
Sustaining university program	46,000
Launch vehicle development	128,200
Bioscience	31,000
Meteorological satellites	37,500
Communication satellites	12,600
Advanced Technological satellites	31,000
Basic research	21,000
Space vehicle systems	38,800
Electronic systems	28,400
Human factor systems	16,200
Nuclear-electric systems	48,100
Nuclear rockets	58,000
Chemical propulsion	59,800
Space power	13,000
Aeronautics	37,000
Tracking and data acquisition	267,900
Technology utilization	5,000
Total, research and development	4,382,000
Construction of facilities	281,000
Total	5,304,000

Procurement

During this period, the Agency continued to make improvements in its procurement management, policies, and practices.

Procurement Conference.—NASA held its annual procurement conference at Ames Research Center, Moffett Field, Calif., from October 30 through November 2. Executive management and procurement personnel from NASA Headquarters and procurement personnel from each field installation attended the conference. Current and proposed procurment policies and procedures were discussed with a view toward improving them. Major policies discussed included (1) incentive contracting, (2) technical direction of contractors, (3) contractor performance evaluation, and (4) service type contracts.

NASA Industrial Property Control Manual.—NASA Industrial Property Control Manual (NPC–105), October 1963 Edi-

TABLE 2.—*Status of appropriations as of December 31, 1963*

[In thousands]

Appropriations	*Obligations*	*Disbursements*[1]
Administrative Operations		
Research and development:		
Gemini	$219,822	$157,986
Apollo	892,496	769,423
Advanced missions	2,455	4,352
Completed missions	250	9,743
Geophysics and astronomy	48,237	45,264
Lunar and planetary exploration	110,907	95,237
Sustaining university program	6,841	3,873
Launch vehicle development	64,077	61,020
Bioscience	6,292	5,305
Meteorological satellites	18,667	27,335
Communication satellites	9,632	14,368
Advanced technological satellites	248	343
Unmanned vehicle procurement	51,990	53,275
Basic research	6,788	8,976
Space vehicle systems	16,355	18,860
Electronic systems	6,405	7,016
Human factor systems	5,205	3,458
Nuclear electric systems	19,927	18,422
Nuclear rockets	31,177	41,527
Chemical propulsion	20,374	26,072
Space power	3,044	3,309
Aeronautics	2,775	5,804
Tracking and data acquisition	59,314	51,249
Technology utilization	500	723
Personnel costs	148,632	147,399
Operation of installation	94,554	107,483
Reimbursable	24,184	30,706
Total, research and development	1,871,148	1,718,528
Construction of Facilities	199,690	156,554

Appropriation summary	*Current availability*	*Total obligations*	*Unobligated balance*
Administrative operations	$494,000	————	$494,000
Research and development	4,097,016	$1,871,148	2,225,868
Construction of facilities	1,073,318	199,690	873,628
Total	5,664,334	2,070,838	3,593,496

[1] This column lists all disbursements during this reporting period, including funds previously obligated.

tion, established the detailed procedures for maintaining control over Government property furnished to or acquired by NASA industrial contractors according to the terms of their contracts. It also set forth the duties and responsibilities of (1) NASA procurement personnel engaged in the administration of NASA contracts, (2) military personnel assisting NASA, and (3) contractors charged with the control of Government property.

Publicizing Procurement Actions.—A letter of September 6 revised NASA Procurement Regulations (part 1, subpart 10). This letter reflected the changes in preparation and handling of synopsized procurement information to accomplish classification by commodities and services in the "Commerce Business Daily."

New Equal Employment Opportunity Clause.—Interim instructions were issued setting forth a new Equal Opportunity clause as prescribed by Executive Order 11114 of June 22. These instructions extended the program for nondiscrimination in employment in Government contracts established by Executive Order 10925 of March 6, 1961. Unless exempted, the new clause is required in NASA contracts and federally assisted construction contracts under NASA grants and other contractural arrangements.

New Facilities Nondiscrimination Clause in Government Leases.—NASA Circular 291, dated August 26, adopted a new policy to include a Facilities Nondiscrimination clause in NASA leases when the total rental exceeds $10,000 per year. This policy was adopted because Federal employees belonging to minority groups and other members of minority groups doing business with the Federal Government in some parts of the country have been denied the use of public facilities located in buildings where the Government leases office space.

Significant Procurement Issuances

NASA developed and issued a number of regulations designed to provide guidance and assistance to procurement personnel. The more significant of these regulations are as follows:

Debarred, Ineligible, and Suspended Bidders.—Extensive revisions were made to this regulation. These revisions include (a) a provision that debarment or suspension of a bidder may include a bidder's affiliates; (b) a reduction of the maximum period of debarment from 5 to 3 years, but additional periods of debarment may be ordered if justified by new facts; (c) a provision that a contractor who violates the "Nondiscrimination in Employment" clause may be considered ineligible for awards; (d) a more thorough detailing of procedures for informing contractors of proposed debarment actions, and for contractor's presentation of evidence in their behalf; and (e) a requirement that suspended contractors be informed of the reasons for their suspension and that evidence regarding suspension be assessed by the Government according to prescribed standards.

Source Evaluation Board Procedures.—These procedures were revised to remove the implication that source evaluation boards are to be used only for competitive negotiated R&D procurements. The regulation now prescribes that such boards are appropriate for use in all competitive negotiated procurements in excess of $1 million and for certain types of service contracts.

Architect-Engineer Services.—This regulation was amended by adding a new provision which authorizes the use of a simplified procedure in selecting architect-engineer firms to perform services that are estimated to cost $10,000 or less.

Justification for Noncompetitive Procurement.—This is a new regulation requiring that a statement be submitted justifying each noncompetitive negotiated procurement, regardless of which exception of 10 U.S.C. 2304(a) is cited and relied on as authority to negotiate. The justification must reflect why other firms in the field lack the particular capability which the proposed contractor evidences.

Noncollusion Certificate.—NASA issued a new regulation adding a requirement that firms submit with their bids or proposals on fixed-price procurements a certificate of noncollusion. They must certify that the price submitted was independently arrived at without collusion with any other bidder, offeror, or any competitor.

Summary of Contract Awards

NASA's procurements for the first 6 months of fiscal year 1964 totalled $1,939 million. This is 48 percent more than was awarded during the corresponding period of FY 1963.

Approximately 76 percent of the net dollar value was placed directly with business firms, 2 percent with educational and other nonprofit institutions and organizations, 7 percent with the California Institute of Technology for operation of the Jet Propulsion Laboratory, and 15 percent with or through other Government agencies.

Contracts Awarded to Private Industry.—Ninety percent of the dollar value of procurement requests placed by NASA with other Government agencies resulted in contracts with industry awarded by those agencies on behalf of NASA. Also, about 81 percent of the funds placed by NASA under the Jet Propulsion Laboratory contract resulted in subcontracts or purchases with business firms. In short, about 95 percent of NASA's procurement dollars was contracted to private industry.

Seventy-five percent of the total direct awards to business represented competitive procurements, either through formal advertising or competitive negotiation. An additional 17 percent represented actions on follow-on contracts placed with companies that had previously been selected on a competitive basis to perform the research and development on the applicable project. In these instances, selection of another source would have resulted in additional cost to the Government by reason of duplicate preparation and investment. The remaining 26 percent included contracts for facilities required at contractors' plants for performance of their NASA research and development effort, contracts arising from unsolicited proposals offering new ideas and concepts, contracts employing unique capabilities, and procurements of sole source items.

With respect to new contracts of $25,000 and over awarded during the year, 60 percent of the aggregate awards represented competitive procurements.

Reflecting the fact that NASA's procurements are primarily for research and development, 83 percent of the awards to business was placed under cost-plus-fixed-fee contracts. However, in line with NASA's policy to include incentive provisions in its contracts, wherever appropriate, the Agency awarded 11 new incentive type contracts and converted 3 cost-plus-fixed-fee contracts and 1 firm-fixed-price contract to incentive type contracts during the period. As of December 31, 1963, NASA had in effect a total of *31* incentive type contracts. Cumulative obligations on these contracts totalled $371 million.

Small Business Participation.—Small business firms received 6 percent of NASA's direct awards to business. Excluding the 20 largest awards which were for major systems and hardware requiring resources not generally within the capability of small business on a prime contract basis, small business received 19 percent of the total awards to business.

In addition to the direct awards to small business, approximately 20 percent of NASA's awards to large business are being subcontracted to small business.

Geographical Distribution of Prime Contracts.—Within the United States, NASA's prime contract awards were distributed among 43 States and the District of Columbia. Business firms in 39 States, educational institutions in 33 States, and other nonprofit institutions in 16 States participated in the awards. *8* percent of the awards were placed in labor surplus areas located in 14 States.

Subcontracting.—Subcontracting effected a further distribution of the prime contract awards. Twelve of NASA's major prime contractors located in 9 States reported that their larger subcontract awards on NASA effort had gone to 1,071 different subcontractors in *44* States and that 73 percent of these subcontract dollars had crossed State lines.

Transportation Studies and Agreements

On November 27, an agreement was signed by NASA and the Military Sea Transportation Service (MSTS) whereby MSTS will modify and operate Landing Ship Dock (LSD) type vessels to transport Saturn stages between the U.S. west coast, New Orleans, and Cape Kennedy. Signing of the NASA/MSTS Agreement constituted a significant step in NASA transportation development and efforts to make maximum use of existing Government resources.

In another area of effort, NASA began devising a transportation system incorporating new equipment concepts to meet the unusual requirements for the Saturn program. A contractor completed a study of transportation requirements related to the Manned Lunar Landing Program. The review was undertaken (1) to ensure that all transportation factors and areas of responsibility are correlated, defined, and planned; (2) to evaluate transportation plans, studies, and reports, including existing and proposed transportation equipment and routes; and (3) to analyze potential problem areas.

The scope and magnitude of transportation requirements are best illustrated by the equipment necessary to support an integrated transportation system. It includes possibly two special purpose LSD type ships, 1 aircraft capable of carrying spacecraft and upper launch vehicle stages, seven special purpose barges, 20 cryogenics and fuel barges, 23 specially designed land transporters, and a variety of associated ground support equipment for use in loading and unloading ships, barges, and aircraft.

Compatible facilities to accommodate the various modes of transport are required, including docks and intraplant roads. Joint participation with Federal and State agencies is necessary in upgrading the capabilities of harbors, waterways, airports, locks, and bridges.

Technology Utilization Program

NASA's Technology Utilization Program before this report period concentrated on identifying new ideas and processes generated by "in-house" space research and development and disseminating this information to industry. During this period, emphasis was placed on encouraging contractors to report technology emerging from their performance, since almost 90 percent of the Agency's research and development funds is spent under contract.

A *new technology clause* will be added to all new NASA contracts and to existing ones when renewed. It requires the contractor to report all new technology in the form of patents, innovations, and advances in the state-of-the-art occurring during the contracting period. The contracting clause, coupled with visits of NASA employees to prime contractors to inform them of the program and enlist their cooperation, is expected to result in an increase in innovations applicable to the civilian economy.

Since its establishment in 1961 the Technology Utilization Program has emphasized the identification of specific innovations (such as techniques, processes, materials, and devices) to accelerate the flow of technical information from space research to nonspace applications. During the report period, emphasis was increased on technology surveys or state-of-the-art summaries likely to be valuable to industry.

A Technology Utilization Report on "An Improved Precision Height Gauge," describing a simple low-cost device for measuring heights with an accuracy of 1 part in 20,000, was published in December. Details and the commercial potential of the device, used in NASA's Ames Research Center for 15 years, had not been previously publicized. In addition, another Technology Utilization film was prepared on the phenomenon of hydroplaning of pneumatic tires—a hazard to aircraft and a threat to runway safety.

How small businesses stand to benefit from the Technology Utilization Program was publicized through the cooperation of the Small Business Administration (SBA). For example, the December issue of the Administration's *Management Aids for*

Small Manufacturers was entirely devoted to a discussion of the program. An SBA distribution of over 200 copies of NASA's Technology Utilization Report on "Selected Welding Techniques," published in May to describe eight welding ideas developed at Marshall Space Flight Center, was well received by businessmen.

A brochure on the goals and activities of the Technology Utilization Program was issued and distributed within NASA and to the Agency's contractors.

Several projects were undertaken to test various techniques for disseminating space research information on a local or regional basis. In addition to the seven-State Midwest Research Institute pilot effort and the Indiana University Aerospace Research Applications Center which works in close cooperation with participating industrial firms, Wayne State University started a related project in the Detroit area consisting of a center for the storage, retrieval, and transfer of new technology to surrounding industry. The project uses industrial engineering graduate students as field engineers.

Appendix A

MEMBERSHIPS OF CONGRESSIONAL COMMITTEES ON AERONAUTICS AND SPACE

(July 1–Dec. 31, 1963)

Senate Committee on Aeronautical and Space Sciences

CLINTON P. ANDERSON, New Mexico, *Chairman*
RICHARD B. RUSSELL, Georgia
WARREN G. MAGNUSON, Washington
STUART SYMINGTON, Missouri
JOHN STENNIS, Mississippi
STEPHEN M. YOUNG, Ohio
THOMAS J. DODD, Connecticut
HOWARD W. CANNON, Nevada
SPESSARD L. HOLLAND, Florida
J. HOWARD EDMONDSON, Oklahoma

MARGARET CHASE SMITH, Maine
CLIFFORD P. CASE, New Jersey
BOURKE B. HICKENLOOPER, Iowa
CARL T. CURTIS, Nebraska
KENNETH B. KEATING, New York

House Committee on Science and Astronautics

GEORGE P. MILLER, California, *Chairman*
OLIN E. TEAGUE, Texas
JOSEPH E. KARTH, Minnesota
KEN HECHLER, West Virginia
EMILIO Q. DADDARIO, Connecticut
J. EDWARD ROUSH, Indiana
THOMAS G. MORRIS, New Mexico
BOB CASEY, Texas
WILLIAM J. RANDALL, Missouri
JOHN W. DAVIS, Georgia
WILLIAM F. RYAN, New York
THOMAS N. DOWNING, Virginia
JOE D. WAGGONNER, Jr., Louisiana
EDWARD J. PATTEN, New Jersey
RICHARD H. FULTON, Tennessee
DON FUQUA, Florida
NEIL STAEBLER, Michigan
CARL ALBERT, Oklahoma

JOSEPH W. MARTIN, Jr., Massachusetts
JAMES G. FULTON, Pennsylvania
J. EDGAR CHENOWETH, Colorado
WILLIAM K. VAN PELT, Wisconsin
R. WALTER RIEHLMAN, New York
CHARLES A. MOSHER, Ohio
RICHARD L. ROUDEBUSH, Indiana
ALPHONZO BELL, California
THOMAS M. PELLY, Washington
DONALD RUMSFELD, Illinois
JAMES D. WEAVER, Pennsylvania
EDWARD J. GURNEY, Florida
JOHN W. WYDLER, New York

Appendix B

Membership of the National Aeronautics and Space Council

(July 1–December 31, 1963)

LYNDON B. JOHNSON, *Chairman (Jan. 20, 1961–Nov. 22, 1963)*
Vice President of the United States

DEAN RUSK
Secretary of State

ROBERT S. MCNAMARA
Secretary of Defense

JAMES E. WEBB, *Administrator*
National Aeronautics and Space Administration

GLENN T. SEABORG, *Chairman*
Atomic Energy Commission

Executive Secretary
EDWARD C. WELSH

Appendix C

Membership of the NASA-DOD Aeronautics and Astronautics Coordinating Board and Vice Chairmen of Panels to Board

(December 31, 1963)

Cochairmen

Dr. ROBERT C. SEAMANS, Jr., Associate Administrator, NASA

Dr. HAROLD BROWN, Director of Defense Research and Engineering, DOD

Members at Large

Admiral W. F. BOONE, USN (Ret.), Deputy Associate Administrator for Defense Affairs, NASA

Mr. DEMARQUIS D. WYATT, Deputy Associate Administrator for Programing, NASA

Dr. ALBERT C. HALL, Deputy Director (Space), DDR&E, DOD

Dr. ALEXANDER H. FLAX, Assistant Secretary of the Air Force (R&D), DOD

Manned Space Flight Panel

Chairman: Dr. GEORGE E. MUELLER, Associate Administrator for Manned Space Flight, NASA

Vice Chairman: Dr. ALEXANDER H. FLAX, Assistant Secretary of the Air Force (R&D), DOD

Unmanned Spacecraft Panel

Chairman: Mr. ROBERT F. GARBARINI, Director of Applications, Office of Associate Administrator for Space Science and Applications, NASA

Vice Chairman: Mr. STARR J. COLBY, Assistant Director (Space Tech nology), DDR&E, DOD

Launch Vehicle Panel

Chairman: Dr. ALEXANDER H. FLAX, Assistant Secretary of the Air Force (R&D). DOD

Vice Chairman: Mr. MILTON W. ROSEN, Office of the Deputy Associate Administrator for Defense Affairs, NASA

Space Flight Ground Environment Panel

Chairman: Brig. General PAUL T. COOPER, USAF, Asst. Director (Ranges & Space Ground Support), ODDR&E, DOD

Vice Chairman: Mr. EDMOND C. BUCKLEY, Director, Tracking and Data Acquisition

Supporting Space Research and Technology Panel

Chairman: Dr. RAYMOND L. BISPLINGHOFF, Associate Administrator for Advanced Research & Technology, NASA

Vice Chairman: Dr. CHALMERS W. SHERWIN, Deputy Director (Research & Technology) ODDR&E, DOD

Aeronautics Panel

Chairman: Rear Admiral NOEL A. M. GAYLER, USN, Director, Development Programs Division, Office of Chief of Naval Operations, DOD

Vice Chairman: Mr. ALBERT J. EVANS, Office of Associate Administrator for Advanced Research and Technology (Acting)

Secretariat

Secretary for DOD: ALBERT WEINSTEIN, DDR&E, DOD

Secretary for NASA: RICHARD J. GREEN, NASA

Appendix D

Inventions and Contributions Board, NASA

(December 31, 1963)

ROBERT E. LITTELL, *Chairman*

PAUL G. DEMBLING, *Vice Chairman*

Members

J. ALLEN CROCKER

C. GUY FERGUSON

GERALD D. O'BRIEN

JOHN B. PARKINSON

JAMES A. HOOTMAN, *Executive Secretary*

Appendix E

Patentable Inventions Recognized by the Agency's Inventions and Contributions Board

(*July 1–December 31, 1963*)

Awards to NASA Employees Under Provisions Of Section 306 of the Space Act of 1958

Invention	Inventor(s)	Employer
Expansion tube for hypervelocity.	Robert L. Trimpi	NASA-Langley RC.
Wedge tails for hypersonic aircraft.	Charles H. McLellan	NASA-Langley RC.
Ion rocket	Harold R. Kaufman	NASA-Lewis RC.

Awards to Employees of NASA's Contractors Under Provisions of the 1958 Space Act

Invention	Inventor(s)	Employer
Bipolar logarithmic current-to-voltage transducer.	Conrad Josias	Jet Propulsion Laboratory.
Space vehicle attitute control	James D. Acord Howard C. Vivian	Jet Propulsion Laboratory.

Awards to NASA Employees Under Provisions Of the Incentive Awards Act of 1954

NASA-AMES RESEARCH CENTER

Invention	Inventor(s)
Dynamic sensor	John Dimeff.
Null-type vacuum microbalance	Vernon L. Rogallo.
Differential temperature transducer	David Wald.

NASA-FLIGHT RESEARCH CENTER

Catalyst bed removing tool	James B. Newman.

NASA-GODDARD SPACE FLIGHT CENTER

Analog-to-digital converter	Henry Doong.
Structural spacer	Jesse M. Madey. Xopher W. Moyer.
Electromechanical analog multiplier	Raymond G. Hartenstein.
A full binary adder	David Schaefer.
Stretch yo-yo de-spin mechanism	Joseph V. Fedor. Henry J. Cornille, Jr.
Accelerometer with FM output	Edward J. Kirchman. Raymond G. Hartenstein.
System for recording and reproducing pulse code modulated data	Pleasant T. Cole.

Awards to NASA Employees Under Provisions Of the Incentive Awards Act of 1954

NASA-LANGLEY RESEARCH CENTER

Invention	Inventor(s)
Solid propellant rocket motor and method of making same	Joseph G. Thibodaux, Jr. Donald J. Lewis.
Coating	Noel T. Wakelyn. Robert A. Jewell.
Aircraft instrument	Joseph W. Wetmore.
Thermal pump-compressor for space use	Franklin W. Booth. Hubert K. Clark.
Heat protection apparatus	Paul R. Hill. Otto F. Trout, Jr.
Target kite	Francis M. Rogallo.
Hypersonic test facility	Frank L. Clark. Charles B. Johnson. Wayne D. Erickson. Roger I. Buchanan.
Micrometeoroid velocity measuring device	William H. Kinard. Charles C. Laney, Jr.
Optical communications device	Numa E. Thomas.
Nacelle afterbody for jet engines	Mark R. Nichols.
Electric-arc heater	Robert F. Mayo. Milton A. Wallio. William L. Wells.
Multiple input radio receiver	James H. Schrader.
Coating process and article	Robert A. Jewell. Noel T. Wakelyn.
Thermal control of space vehicles	Dewey L. Clemmons, Jr.
Pressurized cell micrometeoroid detector	Charles A. Gurtler.
Miniature vibration isolator	David H. Butler. Wilbert C. Falk.

NASA-LEWIS RESEARCH CENTER

Inlet deflector for jet engines	Walter T. Olson.
Multistage multiple-reentry turbine	Warner L. Stewart. David G. Evans.
High temperature spark plug	John E. Watson.
Apparatus for increasing ion beam density	Lionel V. Baldwin. Virgil A. Sandborn.
Electrostatic propulsion system with generator	Charles A. Low, Jr. William R. Mickelsen.
Non-reusable kinetic energy absorber	Earl W. Conrad.
Rocket motor casing and method	Edward F. Baehr.
Meteoroid sensing apparatus	Elmer H. Davison.
High temperature heat source	Alex Vary.
Reinforced metallic composites	J. W. Weeton. D. L. McDanels. R. W. Jech. R. E. Oldrieve. D. W. Petrasek. R. A. Signorelli.
Inverter circuit	John C. Sturman.
Simulated fuel assembly	Joseph M. Savino. Chester D. Lanzo.
Nuclear reactor control rod assembly with improved driving mechanism	John W. Macomber.
Solid state power mapping instrument	Robert Steinberg. William B. Schwab.
Thin-walled pressure vessel	William C. Morgan. Jack B. Esgar. Richard H. Kemp.

Awards to NASA Employees Under Provisions Of the Incentive Awards Act of 1954

NASA-MANNED SPACECRAFT CENTER

Invention	Inventor(s)
Inflatable radar reflector unit	Matthew I. Radnofsky. Glenn A. Shewmake.
Life vest	Matthew I. Radnofsky. Glenn A. Shewmake.
Resuscitation method and apparatus	Laurence M. Christman.

NASA-MARSHALL SPACE FLIGHT CENTER

Invention	Inventor(s)
Electro-optical tooling control	Robert J. Schwinghamer. John R. Rasquin.
Frequency multiplier	Armand P. Lucchesi. Jefferson B. Turner.
Assembly for recovering a capsule	Alfred P. Warren. Billy D. Lawson.
Method and apparatus for securing objects together	Robert J. Schwinghamer.
Seam tracker	Hershel M. Nance.
Secure frequency modulation communications system	Lee B. Malone. Charles E. David. Harold R. Lowry.
Cryogenic storage container	Dolphus H. Black.
Resistance cured filament wound containers	Robert J. Carmody.
Combined pulse and Nth pulse indicator	Jon R. Rehage.
Trigonometric System	Charles E. Lee. Herman E. Thomason. Richard L. Moore.
Electronic motor control system	Harrison N. Thomas.
Missile launching apparatus	Georg von Tiensenhausen.
Calibrationable pressure responsive actuator	Darrell E. Melton.
Condition and condition duration indicator	Thomas L. Greenwood.

Appendix F

Patent Waivers Granted and Denied by NASA Upon Recommendation of the Agency's Inventions and Contributions Board

(July 1–December 31, 1963)

Invention	Petitioner	Action on petition
Missile integrated aerodynamic nozzle rocket.	North American Aviation Inc	Denied July 29, 1963.
Aerodynamic spike-nozzle	do	Do.
Antenna beam-shaping apparatus	California Institute of Technology	Denied Aug. 5, 1963.
Antenna beam-shaping apparatus	do	Do.
Space actuator	General Mills, Inc	Granted Aug. 5, 1963.
Thermal control mechanism for lunar manipulator.	do	Do.
Overload clutch	do	Do.
Balloon-borne sonic anemometer	Cook Electric Co	Do.
Detector mounting and method of making same.	Barnes Engineering Co	Do.
Liquid hydrogen tanking computer apparatus.	Minneapolis-Honeywell Regulator Co.	Granted Oct. 15, 1963.
Transducer for continuous external measurement of arterial blood pressure.	Stanford Research Institute	Do.
Improved magnetic thin film plated wire memory.	Sperry Rand Corp	Granted Oct. 25, 1963.
Method for mounting terminals in circuit boards.	California Institute of Technology	Granted Nov. 19, 1963.

Appendix G

Patent Waivers Recommended for Grant and Denial by the Agency's Inventions and Contributions Board

(July 1–December 31, 1963)

Invention	Petitioner	Board recommendation
Cryogenic flow meter calibrator	North American Aviation, Inc	Denial.
Arithmetic divider circuit	International Business Machines	Grant.
Solid state camera apparatus and system	Electro Radiation, Inc	Do.
Radiant heat attenuator	North American Aviation, Inc	Denial.
Paraglider deployment	do	Do.
Analog-to-digital converter	California Institute of Technology	Grant.
Improved ionization vacuum gage	do	Denial.
Seismometer	do	Grant.
Two-way solenoid valve	North American Aviation, Inc	Do.
Swash-plate gimbal bearing	do	Do.
Ferroelectric bolometer	Ingrao et al. (Harvard College)	Do.
Hypergolic pressurization system	North American Aviation, Inc	Denial.
Pressure responsive ring valve	do	Do.
High speed differential sampler and amplifier.	International Business Machines	Grant.
Microwave frequency doubler	Hughes Aircraft Co	Do.
Airborne sampled data reduction	International Business Machines	Do.
Temperature transducer	Ball Bro. Corp	Do.
Composition of matter and method of making same.	Space Technology Laboratories, Inc	Do.
Keyed connector for plugs and sockets	McDonnell Aircraft Corp	Do.
Fastener-honeycomb noncrush installation.	North American Aviation, Inc	Do.
At assembly tube cleaning tool	McDonnell Aircraft Corp	Do.
At assembly tube cut off tool	do	Do.
Tube end deburring tool	do	Do.
Transient-free phase-lock loop bandwidth switching.	Space Technology Labroatories, Inc	Denial.
An adapter filter for a phase lock loop	do	Do.
Porous body with imperviously sealed outer surface and method.	Kulite Tungsten Co	Grant.
Ion gage	Hughes Aircraft Co	Do.
Dual-wound helix	Space Technology Laboratories, Inc	Do.

Appendix H

Memberships of NASA's Space Sciences Steering Committee and Subcommittees

(December 31, 1963)

SPACE SCIENCES STEERING COMMITTEE

Chairman: JOHN F. CLARK
Secretary: MARGARET B. BEACH

Members

EDGAR M. CORTRIGHT
WILLIS B. FOSTER
ROBERT F. GARBARINI
BENNY B. HALL
LEONARD JAFFE
URNER LIDDEL
JESSE L. MITCHELL
JOHN E. NAUGLE
HOMER E. NEWELL
ORAN W. NICKS
ORR E. REYNOLDS
MORRIS TEPPER

SUBCOMMITTEES [1]

ASTRONOMY

Chairman: NANCY G. ROMAN
Vice Chairman: RONALD A. SCHORN (Acting)
Secretary: ERNEST J. OTT

Members and Consultants

GORDON C. AUGASON, Ames Research Center
A. G. W. CAMERON, Goddard Space Flight Center
GERALD MAURICE CLEMENCE, Yale University Observatory
ARTHUR DODD CODE, University of Wisconsin
JAMES DOZIER, Marshall Space Flight Center
JOHN W. FINDLAY, National Radio Astronomy Observatory (Space Sciences Board, National Academy of Sciences)
JESSE L. GREENSTEIN, Mt. Wilson & Palomar Observatory
KENNETH L. HALLAM, Goddard Space Flight Center
JAMES E. KUPPERIAN, Jr., Goddard Space Flight Center
LEN ROBERTS, Lewis Research Center
EDWIN E. SALPETER, Cornell University
HARLAN J. SMITH, University of Texas
HYRON SPINRAD, Jet Propulsion Laboratory
R. C. STOKES, Manned Spacecraft Center
ALBERT EDWARD WHITFORD, University of California Lick Observatory

[1] Committee and subcommittee members are on the NASA staff.

Biosciences

Chairman: Orr E. Reynolds
Vice Chairman: Urner Liddel
Secretary: Virginia Bolton

Members and Consultants

R. E. Belleville, NASA Headquarters
Allan H. Brown, University of Pennsylvania (Space Sciences Board)
Loren D. Carlson, University of Kentucky
Robert F. Fellows, NASA Headquarters
Sidney Fox, Florida State University
John Douglas French, University of California
Sidney Galler, Office of Naval Research
James P. Henry (Col.), University of Southern California
George L. Hobby, Jet Propulsion Laboratory
Norman H. Horwitz, California Institute of Technology
George J. Jacobs, NASA Headquarters
Dale W. Jenkins. NASA Headquarters
Harold P. Klein, Ames Research Center
Elliot Levinthal, Stanford University
Eric Ogden, Ames Research Center
Colin S. Pittendrigh, Princeton University
Ernest C. Pollard, Pennsylvania State University
Freeman H. Quimby, NASA Headquarters
Carl Sagan, Harvard University
James Newell Stannard, University of Rochester
Hans-Lucas Teuber, Massachusetts Institute of Technology
Richard S. Young, Ames Research Center

Ionospheres and Radio Physics

Chairman: Alois W. Schardt
Vice Chairman: Ronald A. Schorn (Acting)
Secretary: Albert G. Opp

Members and Consultants

Robert E. Bourdeau, Goddard Space Flight Center
Roger Gallet, National Bureau of Standards, Boulder, Colorado
Owen K. Garriott, Stanford University
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Colin O. Hines, University of Chicago
John E. Jackson, Goddard Space Flight Center
Eugene A. Mechtly, Marshall Space Flight Center
Millett G. Morgan, Dartmouth College
Erwin Schmerling, Pennsylvania State University
Carl J. Seddon, Goddard Space Flight Center
John R. Spreiter, Ames Research Center
Thomas Edward Van Zandt, National Bureau of Standards, Boulder, Colorado

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Leo Goldberg, Harvard College Observatory
Robert Benjamin Leighton, California Institute of Technology
John C. Lindsay, Goddard Space Flight Center
Alan Maxwell, Harvard Radio Astronomy Station
Oren Cuthbert Mohler, University of Michigan
Nancy G. Roman, NASA Headquarters

Appendix I

Membership of NASA's Industrial Applications Advisory Committee

(Dec. 31, 1963)

Chairman

WALTER L. LINGLE, Deputy Associate Administrator for Industrial Affairs, NASA.

Members

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ALTON D. ANDERSON, Vice President and General Manager, Tech-Center Division, Cook Technological Center, Morton Grove, Ill.

Executive Secretary

LOUIS B. C. FONG, Director, Technology Utilization Division, OTUPP, NASA Headquarters

Appendix J

NASA's Major Contractors

(July 1–Dec. 31, 1963)

Aerojet-General Corp., [1] Azusa, Calif.

Bellcom, Inc., Washington, D.C.

Bendix Corp., [1] North Hollywood, Calif.

Boeing Co. [1] Huntsville, Ala.

Brown Engineering Co., Huntsville, Ala.

Chrysler Corp. [1] New Orleans, La.

Douglas Aircraft Co., Inc. Santa Monica, Calif.

Ernst/Smith Joint Venture, Orlando, Fla.

General Dynamics Corp. San Diego, Calif.

General Electric Co. [1] Philadelphia, Pa.

General Motors Corp., [1] Milwaukee, Wisconsin

Grumman Aircraft Engineering Corp. Bethpage, N.Y.

Hayes International Corp. [1] Birmingham, Ala.

Ingalls Iron Works Birmingham, Ala.

International Business Machine Corp., [1] Rockville, Md.

Jones J. A. Construction Co., New Orleans, La.

Kollsman Instrument Corp. Elmhurst, N.Y.

Lockheed Aircraft Corp., [1] Sunnyvale, Calif.

McDonnell Aircraft Corp. St. Louis, Mo.

North American Aviation, Inc. [1] Downey, Calif.

Philco Corp. [1] Palo Alto, Calif.

Radio Corporation of America [1] Van Nuys, Calif.

Raytheon Co., [1] Bedford, Mass.

Space Technology Laboratories, Inc., [1] Los Angeles, Calif.

United Aircraft Corp. [1] West Palm Beach, Fla.

[1] Awards during period involve more than one contractor address.

Appendix K

Major NASA Launches, Jan. 1—Dec. 31, 1963

Name, date launched, mission	Launch vehicle	Launch site [1]	Results
Syncom I, Feb. 14. To place satellite in highly elliptical, 24-hour, "Synchronous" Earth orbit; test new satellite attitude and period control concept, Syncom communications performance, and transportable ground facilities. Satellite designed to transmit 1 2-way telephone conversation or about 16 1-way teletype circuits.	Thor-Delta	AMR	Near-syncronous orbit achieved. Communications tests not conducted due to failure to establish contact with satellite Radio contact with satellite lost about 20 seconds after command given to fire apogee motor; until this time all mission events had occurred normally.
Explorer XVII, Apr. 2. To orbit Earth satellite to measure density, composition, pressure, and temperature of Earth's atmosphere at satellite's altitude.	Thor-Delta	AMR	Orbit achieved. Equipment operating as designed.
Telstar II, May 7. To place satellite in elliptical Earth orbit for further research toward future operational worldwide satellite network; study radiation effects and means of extending this type satellite's useful life; check performance of new ground station equipment.	Thor-Delta	AMR	Orbit achieved. Satellite used successfully for several communications tests. These tests included successful transmission of black-and-white and color TV (live and video tape) as well as voice messages between United States, France, and England.
TIROS VII, June 19. To place satellite in near-circular Earth orbit to obtain weather data during forthcoming storm season; measure Earth-Sun heat balance relationships; obtain electron temperature data.	Thor-Delta	AMR	Orbit achieved. All instrumentation performed as designed.
Mercury-Atlas IX, May 15. To place manned spacecraft in Earth orbit and recover in preplanned area after 22 orbits; study effects of about 1 day's orbital flight on astronaut; verify that man can function in space as primary spacecraft system; check performance of astronaut and spacecraft modified for 1-day mission.	Atlas D	AMR	Objectives achieved. Astronaut Leroy G. Cooper and spacecraft recovered about 80 miles S.E. of Midway and placed aboard Carrier *Kearsarge* at 8 p.m. e.d.t., May 16.
Syncom II, July 26. To place satellite in 24-hour "synchronous" orbit; test new approach to satellite attitude and period control; obtain experience in using communications satellite in 24-hour orbit.	Thor-Delta	AMR	Figure 8 synchronous orbit achieved; attitude and period control operating as designed; communications equipment successful for transmission of teletype, telephone and facsimile between North America, Africa and South America.

[1] AMR—Atlantic Missile Range, Cape Kennedy, Fla.; PMR—Pacific Missile Range, Point Arguello, Calif.

Major NASA Launches, Jan. 1—Dec. 31, 1963—Continued

Name, date launched, mission	Launch vehicle	Launch site [1]	Results
Explorer XVIII, Nov. 26. To place satellite in highly elliptical Earth orbit to survey charged particles radiating from Sun and sources beyond the Sun; obtain data on Earth's and Sun's magnetic fields; study night side of magnetosphere.	Thor-Delta	AMR	Objectives achieved. Mapped radiation at a height of over 122,000 miles or more than half way to the moon.
Centaur, Nov. 27. To demonstrate Atlas Centaur structural capability, to test second stage ignition, and guidance accuracy. After 4 minutes Atlas burn time, separate and ignite Centaur; after 380 seconds Centaur burn time, place this spent stage in orbit.	Atlas-Centaur	AMR	Objectives achieved; 5-ton payload placed in planned earth orbit. Atlas and Centaur performed as planned. First successful U.S. launch of large liquid-hydrogen booster.
Explorer XIX, Dec. 19. (Air density drag measurement satellite, or "polkadot balloon.") To investigate atmospheric density, temperature, and pressure, measure solar-cycle effect on atmospheric density in upper latitudes; test Scout launch vehicle.	Scout	PMR	Orbit achieved. Launch vehicle performed as planned. Tracking beacon failed, but satellite tracked optically to obtain atmospheric density data desired.
TIROS VIII, Dec. 21. To place satellite in near-circular Earth orbit to obtain photographic data on Earth's cloud cover; test Automatic Picture Transmission (APT) system.	Thor-Delta	AMR	Objectives achieved; orbit achieved; all equipment including APT, operated as designed.

[1] AMR Atlantic Missle Range, Cape Kennedy, Fla.; PMR—Paciffc Missle Range, Point Arguello, Calif.

Appendix L

NASA Launch Vehicles

Vehicle	Stages	PAYLOAD IN POUNDS			Principal use
		345-mile orbit	Escape	Mars/ Venus	
Scout	1	150–220			Launching small scientific satellites and probes (Explorer).
Delta	3	800	120		Launching scientific, meteorological, and communications satellites (TIROS, Orbiting Solar Observatory, OSO–1, Ariel, Telstar I, Relay, and Syncom II).
TAD (Thrust Augmented Delta).	3	1,000	150	120	Launching scientific, meteorological, communications, and bioscience satellites and lunar and planetary probes. (Pioneer A–D, TIROS K, TIROS operational satellite OT–3 and OT–2, Syncom C (A–27), Biosatellite C–F).
Thor-Agena B	2	1,600			Launching scientific and applications satellites (Echo II, Nimbus, Polar Orbiting Geophysical Observatory).
TAT (thrust augmented Thor-Agena).	2	2,200			Launching geophysics and astronomy, and applications satellites (OGO–C, D, F, and Nimbus B).
Atlas-Agena B	2½	5,000	750	400	Launching heavy scientific satellites, lunar and planetary probes (Ranger, Mariner).
Atlas-Centaur	2½	8,500	2,300	1,300	Launching heavy unmanned spacecraft for lunar soft landers (Surveyor).
Atlas D	1	[1]			Launching manned Mercury spacecraft.
Titan II	2	7,000, 87/161 elliptical orbit.			Launching manned spacecraft (Gemini).
Saturn I (formerly Saturn C–1).	2	20,000 (15,000 without restart capability).			Project Apollo.

[1] Only NASA application is Project Mercury—2,500 pounds in 114-mile orbit.

NASA Launch Vehicles—Continued

Vehicle	Stages	PAYLOAD IN POUNDS			Principal use
		345-mile orbit	Escape	Mars/ Venus	
Saturn I–B (formerly Saturn CIB).	2	28,500			Project Apollo.
Saturn V (formerly Advanced Saturn C–5).	3	220,000	90,000	70,000	Project Apollo.

[1] Only NASA application is Project Mercury—2,500 pounds in 114-mile orbit.

Appendix M

RESEARCH GRANTS AND CONTRACTS

(July 1, 1963 through December 31, 1963)[1]

State and grant or contract number	Organization, investigator and purpose	Amount
Alabama:		
NASr-117	Southern Research Institute, J. R. KATTUS. Investigative research of protective coating for sheet steels in supersonic transport aircraft.	$25,163
Arizona:		
NsG-120	University of Arizona, R. W. G. WYCKOFF. Research on generation, detection and quantitative measurement of ultra-long wavelength X-rays.	50,025
NsG-487	University of Arizona, A. P. WILSKA AND G. P. KUIPER. High resolution electron microscopic techniques for studying biological material.	15,000
NsG-490	University of Arizona, L. E. WEAVER. Research in the application of modern automatic control theory to nuclear rocket dynamics and control.	58,413
NsG-493	University of Arizona, A. M. J. GEHRELS. Analysis and reduction of photometric and polarimetric observation of planets and other objects in the solar system.	9,168
NsG-(F)-15	Lowell Observatory, JOHN HALL. Construction of a planetary research center.	236,520
California:		
NsG-81	Stanford University, J. LEDERBERG. Cytochemical studies of planetary microorganisms.	132,000
NsG-170	University of California (Berkeley), NELLO PACE. Conduct experimental research on hemodynamic and related physiologic functions in primates.	171,377
NsG-237	University of California (Los Angeles), W. F. LIBBY. Interdisciplinary space-oriented research in the physical, biological and engineering sciences.	110,000
NsG-243	University of California (Berkeley), S. SILVER. Interdisciplinary space-oriented research in the physical, biological and engineering sciences.	540,000
NsG-318	University of California (San Diego), L. E. PETERSON. Experimental research on X- and gamma-radiation at high altitudes, including design and use of balloon-borne instrumentation.	90,000
NsG-319	University of California (San Diego), G. G. GOLES. Geochemistry of trace elements in meteorites.	16,257
NsG-331	Stanford University, A. L. SCHAWLOW. Spectroscopic studies in infrared and optical quantum electronics.	150,000
NsG-357	University of California (San Diego), G. BURBRIDGE. Theoretical research in astrophysics.	14,000
NsG-397	University of California (Berkeley), N. PACE. A study of the physiological mechanisms of hibernation in hibernators living at high altitudes.	152,290
NsG-479	University of California (Berkeley), H. JONES. The chemistry of living systems.	403,548

[1] Contracts have prefix NAS; Grants have prefix NsG; Transfer of Funds to Government Agencies have prefix R. Earlier Grants and Contracts are listed in appendices of previous NASA Semi-annual Reports to Congress.

State and grant or contract number	Organization, investigator and purpose	Amount
California—Con.		
NsG-502	University of California (Los Angeles), J. D. FRENCH Neurophysiological and behavioral studies of chimpanzees, including establishment of a group of implanted animals suitable for space flight.	$150,000
NsG-505	University of California (Los Angeles), JOHN D. FRENCH A study of brain function through advanced computer techniques for analysis of electronencephalographic data.	69,190
NsG-510	Medical Sciences Research Foundation, M. WINITZ An experimental study and clinical evaluation of the dietary requirements of man, particularly astronauts, with emphasis on water-soluble chemically-defined diets suitable for space flight missions.	412,452
NsG-513	University of California (Berkeley), NELLO PACE Private hemodynamics and metabolism under conditions of weightlessness, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	80,368
NsG-515	University of California (Los Angeles), W. R. ADEY Monitoring brain functions and performance in the monkey under prolonged weightlessness for the purpose of defining and verifying an experiment for use in a biosatellite.	92,394
NsG-528	University of California (Los Angeles), T. HOSHIZAKI Effect of space environment on circadian rhythms of plants, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	25,277
NsG-534	University of California (San Diego), J. R. ARNOLD Study of lunar gamma ray emission.	50,477
NsG-535	California Institute of Technology, F. E. LEHNER Unmanned refraction seismic studies of the lunar surface including the development of a technique for deployment and ranging of controlled explosives.	68,410
NsG-541	University of California (San Diego), H. C. UREY Analysis of the organic and inorganic constituents of carbonaceous and other selected stoney meteorites.	78,974
NsG-549	Medical Sciences Research Foundation, W. L. CHAN An experimental protocol for studies of circadian rhythms in humans.	10,680
NASr-8	Astro Research Corporation, H. R. SCHUERCH A theoretical and experimental study of toroidal filamentary pressurized structures based on isotensoid design concepts including initial studies of failure mechanisms, collapsibility and possible application of isotensoid concepts to the design of space structures.	2,483
NASr-21(05)	Rand Corporation, E. H. VESTINE Conduct theoretical studies of the earth's magnetic field and the space environment near earth.	15,724
NASr-49(02)	Stanford Research Institute, W. R. VINCENT (a) Investigation of potential interference between ground microwave communications and proposed satellite communication systems on shared frequency bands. This study shall include determination of spectrum separation requirements, development of mathematical models of ground and satellite systems, etc.	
NASr-49(16)	Stanford Research Institute, R. B. VAILE, JR Research into magnetic susceptibility of selected pure organic compounds.	52,674
NASr-49(17)	Stanford Research Institute, R. K. ARNOLD Preparation of information on, and analysis of, the problems of economic impact of a facility on selected areas.	10,862
NASr-188	Long Beach State College Foundation, E. E. Collins The development of aero-space materials for enrichment in aerospace education in the public schools.	7,800

State and grant or contract number	Organization, investigator and purpose	Amount
California—Con.		
NASr-195	Stanford Research Institute, N. K. KIESTER Partial support of an International symposium on high temperature technology to provide information regarding high temperature research activities in the interchange of high temperature information.	$3,600
NASw-81	California Institute of Technology, H. BENLOFF Investigation of the moon with a lunar seismograph station.	
NsG-(F)-10	University of California (Los Angeles) Construction of a space science building connected with the geology and chemistry buildings on the campus at UCLA.	2,000,000
Colorado:		
NASr-147	Colorado State University, W. E. MARLATT Investigation of the temperature and spectral emissivity characteristics of cloud tops and of the earth's surface.	38,039
NASr-185	University Corporation for Atmospheric Research, W. O. ROBERTS Develop balloon systems and conduct high-altitude balloon flights.	175,000
R-101	U. S. National Bureau of Standards, W. R. SCOTT Provision and operation of ground receiving equipment for observation of beacon satellite.	142,000
R-110	U. S. National Bureau of Standards, W. H. CAMPBELL Construct and install three-component coil magnetometers at each of ten existing micropulsation ground support stations.	90,000
NsG-(F)-9	University of Colorado, WILLIAM A. RENSE Construction of a building housing laboratories for atmospheric and space physics on the Boulder campus of the U. of Colorado.	792,000
Connecticut:		
NsG-309	University of Connecticut, D. P. LINDOOFF Analytical and experimental research on methods of reducing the sensitivity of sampled data systems to parameter variations and disturbances.	24,000
NASr-202	University of Bridgeport To produce materials in astronomy and space sciences for elementary school science teachers.	7,776
District of Columbia:		
NsG-34	National Academy of Sciences Participation in the Resident Research Associateships Program.	1,000,000
NsG-71	Smithsonian Institution, E. P. HENDERSON Tektite collection and study.	20,000
NsG-87	Smithsonian Institution, FRED L. WHIPPLE Optical satellite tracking program.	649,998 650,000 650,000
NsG-364	National Academy of Sciences, A. S. ROMER Partial support for the XVI International Congress of Zoology.	20,000
NsG-388	Georgetown University, STANLEY A. ZIEMNOWICZ An investigation of the dynamics of cerebral circulation by continuous rheoencephalographic monitoring.	90,000
NsG-486	National Academy of Sciences Partial support of the Cold Spring Harbor symposium on molecular biophysics.	10,000
NsG-564	National Academy of Sciences, JOHN S. COLEMAN Prepare and publish 100 copies of a final comprehensive summary report of the entire scientific proceedings of the 1963 XIV.	8,000
NASr-132	American Institute of Biological Sciences, FRANK FREMONT-SMITH Conduct symposium on the minimum ecological systems for man.	60,365
NASr-182	National Academy of Sciences, C. J. WESSEL Partial support for the Prevention of Deterioration Center.	80,000

State and grant or contract number	Organization, investigator and purpose	Amount
District of Columbia—Con.		
R-42	U.S. Navy—Office of Naval Research Provide partial support for the National Research Council Committee on Hearing and Bio-acoustics and the National Research Council Committee on Vision.	$12,500
R-80	U.S. National Bureau of Standards, M. J. Berger Studies of the penetration of high-energy radiation through matter.	15,000
R-98	U.S. National Bureau of Standards, D. I. Mittleman Interagency fund transfer to NBS covering work required to develop standard mensurative computer tasks.	8,315
R-109	U.S. Navy—Bureau of Naval Weapons Study of the application of the Tuphon Ramjet for propulsion tests on the X-15.	51,000
R-112	U.S. Air Force—Office of Scientific Research, B. F. Chow Studies of the effect of space-related environmental conditions on the absorption and metabolism of minerals.	20,000
NsG-536	Smithsonian Institution, F. J. Whipple Optical and radar investigations of simulated and natural meteors.	205,738
NASr-196	Aerospace Medical Association, W. Kennard Services and materials necessary to administer a program for publication and distribution of current medical abstracts.	6,500
R-14	U.S. National Bureau of Standards, J. A. Bennett Effect of surface reactions on fatigue failure, (Cont. NTF-97)	22,000
R-51	U.S. National Bureau of Standards, G. B. Schubauer Conduct investigation of the mechanism of transition from laminar to turbulent flow in boundary layers in both subsonic and supersonic flows.	160,000
R-66	U.S. Dept. of Interior (Geological Survey), F. E. Senftle Conduct studies of the lunar surface, including lunar geologic mapping; cratering and other crater impact mechanisms; chemical, physical and petrographic properties of material of possible lunar origin; and ranger and surveyor data reduction and interpretation.	164,050 492,150
R-102	U.S. National Bureau of Standards To provide for a worldwide patrol of solar flare activity.	75,000
R-103	National Science Foundation, C. M. Stearns Partial support for the Smithsonian Institution for Science Information.	395,000
R-104	U.S. Atomic Energy Commission, Blizard, Maienschein and Zerby Perform theoretical and experimental studies of the penetration of space vehicle structural material, at Oak Ridge National Laboratory.	2,150,000
R-107	U.S. Navy—Naval Research Laboratory, H. Friedman Conduct a broad program in solar instrumentation design.	548,000
R-111	U.S. Navy—Bureau of Naval Weapons Partial support of the Chemical Propulsion Information Agency (CPIA), of Interagency Chemical Rocket Propulsion Group (ICRPG) for collection, cataloging and dissemination of solid and liquid propellant systems information.	95,000
Florida:		
NsG-278	Communication Research Institute of St. Thomas, V. I. John C. Lilly A study of the feasibility and methodology for establishing communication between man and other species.	36,475
NsG-507	University of Florida, J. N. Webb Reciprocal effects of space launching activities upon surrounding area population, trade, industrial development and the labor market.	40,000

State and grant or contract number	Organization, investigator and purpose	Amount
Florida—Con.		
NsG-508	Florida State University, C. M. GRIGG. Study of the effects of a rapid increase in space related activities on a multiple community area, including: the ability to assimilate newcomers into the communities, local governments' ability to meet the needs for their rapid expansion, and interjurisdiction relationships in a consolidating area of multiple local governments.	$58,750
NsG-512	University of Florida, P. O. Lowdin. Quantum theory studies of the energies of excited state atoms and molecules particularly as they occur in the upper and stellar atmospheres and in materials undergoing combustion.	125,000
NsG-527	Florida State University, A. G. DEBUSK. Genetic effects on neurospora resulting from possible synergism between weightlessness and radiation, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	52,998
NsG-542	University of Florida, L. E. Grinter. Multidisciplinary program of research in space-related sciences and technology.	670,000
NASr-204	East Central Florida Regional Planning Council, R. H. DOYLE. Study of loading effects on land, highways and utilities produced by a rapid increase in an area's space-related activities, and means of minimizing these area impact problems.	24,000
R-93	U.S. Navy—School of Aviation Medicine, A. GRAYBEIL. Research on the role of the vestibular organs in space flight.	500,000
Georgia:		
NsG-521	Emory University, S. W. GREY. The effect of weightlessness and radiation on the growth of the wheat coleoptile, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	13,950
NsG-545	Emory University, T. FORT. Research in difference equations with varying difference interval and difference, and difference equations with almost periodic coefficients.	13,856
NsG-529	Emory University, B. F. EDWARDS & S. W. GRAY. The effect of zero gravity and radiation on the growth of tissues in vitro, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	19,600
Illinois:		
NsG-24	University of Illinois, G. W. SWENSON, JR. Investigation of the ionosphere using signals from Earth satellites.	119,083
NsG-96	University of Chicago, E. N. PARKER. Theoretical investigation of further consequences of solar wind.	111,450
NsG-179	University of Chicago, JOHN SIMPSON. Conduct experimental and theoretical studies of energetic particles and electrodynamical processes in interplanetary space and in the vicinity of planets.	100,000
NsG-242	University of Illinois, B. T. CHAO. Theoretical and experimental study of thermal contact resistance in a vacuum environment.	56,137
NsG-276	University of Chicago, J. BURNS. Determination of future image converter requirements for orbiting observatories, methods for meeting these requirements, and experimental studies of possible image tube materials.	70,000
NsG-333	University of Chicago, T. FUJITA. Meteorological interpretation of satellite radiation data.	110,000
NsG-366	University of Chicago, E. ANDERS. Mass spectrometry and electron microprobe studies.	31,941
NsG-443	University of Illinois, H. KNOEBEL. Two-year program research on an experimental test of relativity.	180,000

State and grant or contract number	Organization, investigator and purpose	Amount
Illinois—Con.		
NsG-467	University of Chicago, C. O. HINES An investigation of the upper atmosphere dynamics.	$93,931
NsG-495	Northwestern University, A. H. RUBENSTEIN Studies and analyses of problems related to the management of scientific research and development.	112,000
NsG-504	University of Illinois, D. ALPERT In support of rocket studies of the upper atmosphere during the IQSY.	155,540
NsG-511	University of Illinois, S. A. BOYHILL Investigations and studies of electron density and collision frequency in the lower ionosphere (D and E regions).	118,150
NsG-546	University of Chicago, W. A. HILTNER Study and evaluation of electronography.	9,425
NASr-65(02)	Armour Research Foundation, WEIL, SELIG & VEY Conduct studies of lunar soil mechanics, including the determination of static mechanical properties of simulated lunar soils under lunar-like environmental conditions.	140,228
NASr-65(03)	Armour Research Foundation, LAWRENCE CONROY Conduct a NASA technology utilization program exhibit at the Chicago International Trade Fair beginning June 19, 1963.	78,557
NASr-65(07)	Armour Research Foundation, G. A. ZERLANT Investigation of light scattering in highly reflecting pigmented coatings.	39,903
Indiana:		
NsG-408	Indiana University, S. ROBINSON An experimental investigation of anaerobic work capacity of humans as affected by stress.	50,000
NsG-503	Indiana University, HOLLIS R. JOHNSON A theoretical investigation of the steady-state interaction between radiation and matter in stellar atmospheres.	21,293
Kansas:		
NsG-530	University of Kansas Medical Center, J. W. THUROW Respiratory movements in ambystoma in a zero-gravity field, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	4,805
NsG-531	University of Kansas Medical Center, G. R. THUROW Orienting behavior of ambystoma in a zero-gravity field, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	5,214
Maine:		
NASr-197	Hebron Academy, J. R. TWITCHELL Six-week study-workshop in the area of "Mathematics Oriented Space Science".	4,100
Maryland:		
NsG-189	University of Maryland, J. D. FINDLEY Conduct behavioral research and experimental analysis of complex behavioral repertoires under full environmental control.	179,367
NsG-435	University of Maryland, LESLIE C. COSTELLO The relationship of biochemical activity to environmental adaption and developmental changes in ascaris.	34,375
NsG-450	University of Maryland, I. GOLDIAMOND & C. B. FERSTER Experimental studies of perceptual processes.	68,253
NsG-520	Johns Hopkins University, J. PEREZ-CRUET Psychocardiovascular reactions during conditions of weightlessness, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	60,000
R-63	U.S. Navy—Medical Research Center, H. T. MERYMAN Conduct an experimental investigation of the mechanism by which freezing or drying and associated effects affect living cells.	26,625

State and grant or contract number	Organization, investigator and purpose	Amount
Maryland—Con.		
R-78	National Institutes of Health, FINN AND STONE Aid in the operation of a regional research center at the Massachusetts Institute of Technology for the development of portable LINC computers and for dissemination of these computers to the biological community.	$100,000
Massachusetts:		
NsG-107	Massachusetts Institute of Technology, THOS. B. SHERIDAN Feedback information criteria for functional extension of human hands.	69,000
NsG-149	Massachusetts Institute of Technology, G. C. NEWTON, JR. Conduct research on vibrator-output angular motion sensors.	39,791
NsG-254	Massachusetts Institute of Technology, C. S. DRAPER Analytical and laboratory investigations to determine information on possible guidance, navigation, control system and instrumentation concepts and configurations for spacecraft having long term earth orbit lunar and planetary missions.	203,965
NsG-262	Harvard University, JOSEPH A. CONNOR Interdisciplinary studies of the effects of high energy protons on biologic systems, including participation in the nationwide cooperative study on shielding materials as related to the Apollo Mission.	215,153
NsG-355	Northeastern University, S. S. SANDLER Theoretical study of antenna problems in radio astronomy.	16,837
NsG-419	Massachusetts Institute of Technology, A. H. BARRETT Electromagnetic investigations of planetary and solar atmospheres and the lunar surface.	410,000
NsG-438	Harvard College Observatory, LEO GOLDBERG Theoretical and experimental studies in ultraviolet solar physics, including construction of laboratory prototype flight experiments.	450,000
NsG-496	Massachusetts Institute of Technology, J. V. HARRINGTON Multidisciplinary research in the space related physical, engineering, social and life sciences.	2,000,066
NsG-540	Brandeis University, J. S. GOLDSTEIN Theoretical studies in radiative transfer in planetary atmosphere and rarified gases, and in related topics of astrophysical interest.	24,608
NASr-58	BOLT, BERANEK AND NEWMAN, INC. Conduct research directed toward the establishment of criteria for evaluating the subjective noisiness of aircraft sounds.	49,785
NASr-189	Lowell Inst. Cooperative Broadcasting Council, SWARTZ The production of 7½ hour "Science Reporter" television programs.	70,000
NASr-193	American Meteorological Society, K. SPENGLER Extend NASr-96 for the abstracting and indexing in the 63 vol. of Meteorological Abstracts.	75,000
R-92	U.S.A.F.—Cambridge Research Center, H. E. HINTEREGGER Conduct measurements, from rockets, of the ultraviolet spectrum as a function of altitude and wavelength.	372,000
NsG-(T)-89	Harvard University, ROSS A. MCFARLAND Support the training of three post-M.D. students in the field of aerospace medicine.	70,200
NsG-(F)-8	Massachusetts Institute of Technology, CHARLES H. TOWNES Construction of a center for space research.	3,000,000
Michigan:		
NsG-2	University of Michigan, F. J. BEUTLER Research on information and communication theory pertinent to the very low signal-to-noise ratios that are encountered in space communication and telemetry.	36,400

State and grant or contract number	Organization, investigator and purpose	Amount
Michigan—Con.		
NsG-39	University of Michigan, F. G. Hammitt Investigation of cavitation-erosion phenomena. (Cont. of NAw-6550).	$71,750 74,875
NsG-472	University of Michigan, R. E. Hiatt Study of plasma sheath associated with communications blackout.	50,000
NsG-475	Michigan State University, L. O. Augenstein Selected studies of molecular organization and mental function.	83,526
NsG-498	University of Michigan, D. C. Pelz Investigation and analysis of the basic factors in a scientific research environment.	29,000
NsG-514	Michigan State University The effect of weightlessness and other stresses associated with flight in space vehicles on pathogenicity and immunity, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	43,941
NsG-516	Michigan State University, W. D. Collings Renal and vascular changes produced by weightlessness, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	56,297
NsG-525	University of Michigan, G. R. Carignan Theoretical investigation of space charge waves in the ionosphere and of space vehicle plasma sheaths.	30,125
NASr-201	Wayne State University, Louis B. Alcorta Contract to conduct a workshop of life sciences in space age setting.	10,815
Minnesota:		
NsG-327	Mayo Association, E. H. Wood Cine roentgenographic study of the heart and lungs of man during exposure to forward acceleration.	47,440
NsG-461	University of Minnesota, Allan H. Brown A conference on atmospheric microbiology.	15,958
NsG-517	University of Minnesota, F. Halberg Spectra and cross-spectra of metabolic rhythms (Circadian and other) in inbred C mice as a temporal gauge of mammalian performance in extraterrestrial space, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	42,684
NsG-522	University of Minnesota, A. H. Brown & A. O. Dahl Plant morphogenesis under weightlessness, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	21,038
NsG-554	University of Minnesota, A. H. Brown Measurement of photosynthetic and respiratory rates, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	35,698
Missouri:		
NASr-63(03)	Midwest Research Institute, M. H. Thornton Aid and encourage the industries of the states of Missouri, Oklahoma, Kansas, Arkansas, Iowa, and Nebraska to participate in space technology, in order that the industries will be strengthened by application of the technology, etc.	96,463
R-108	U.S. Aeronautical Chart & Information Center Support lunar topographic services.	200,000
Nebraska:		
NASr-205	Lincoln Public Schools, S. N. Watkins To develop specific space-related teaching materials designed to serve as guides and supplements to classroom instruction.	8,950

State and grant or contract number	Organization, investigator and purpose	Amount
New Hampshire:		
NASw-155	University of New Hampshire, L. J. CAHILL Develop, construct and test four (4) magnetometer instruments suitable for use on a satellite to determine the magnitude and direction of the Earth's magnetic field and analyze telemetered data from the instrument.	$20,000
New Jersey:		
NsG-69	Princeton University, M. SCHWARZSCHILD The use of television techniques with telescopes above the atmosphere.	200,000
NsG-200	Princeton University, MARTIN SUMMERFIELD Conduct research on ignition, and combustion stability and efficiency, of solid propellants at low pressures.	50,680
NsG-306	Princeton University, JAHN, KUNNEN AND BERNSTEIN Theoretical and experimental studies of the formation and stability of the magnetogasdynamic front in a pinch discharge.	130,205
NsG-326	Stevens Institute of Technology, J. ANDERSON Conduct research on principles of general covariance in its various formulations and the related problems of the role of coordinates in general relativity.	13,466
NsG-389	Princeton University Analytical studies of nuclear rocket propulsion and systems.	44,150
NsG-470	Princeton University, C. S. PITTENDRIGH An experimental analysis of circadian rhythms under terrestrial conditions, including techniques for studying rhythms in an orbiting satellite.	42,926
NsG-494	Stevens Institute of Technology, L. Z. POLLARA A quantitative study of solutions through gas chromatography.	27,963
NsG-556	Princeton University, W. M. ELSASSER Study of the application of the Law of Solid Creep to convective motions in the Earth's mantle, the Moon and planets.	11,200
NASr-108	General Electric Company, L. F. EPSTEIN Review and critically evaluate the available information on liquid alkali metal technology.	22,187
NsG-(F)-14	Princeton University, J. P. LAYTON Construction of a basic research laboratory wing of the Guggenheim Laboratories for the Aerospace Propulsion Sciences.	625,000
New Mexico:		
NsG-129	University of New Mexico, R. K. MOORE Investigate radar echoes from the moon and planets, using methods and data from Earth radar-return studies.	30,990
NsG-279	University of New Mexico, W. W. GRANNEMANN Research on hall effect for low voltage, high current d.c. and a.c. conversion.	34,992
NsG-332	University of New Mexico, C. P. LEAVITT Design and development of an experiment to measure the high energy neutron flux in space.	20,000
New York:		
NsG-48	Rensselaer Polytechnic Institute, E. H. HOLT Investigation of the properties of gaseous plasmas by microwave techniques.	7,020
NsG-112	Columbia University, LAWRENCE O'NEILL Methods for determining blood flow through intact vessels of experimental animals under conditions of gravitational stress and in extraterrestrial space capsules.	98,639
NsG-167	New York University, SERGE A. KORFF Theoretical research on cosmic rays, neutrons and interplanetary plasma in the solar system.	15,000
NsG-229	Columbia University, ARTHUR N. STRAHLER Conduct a summer institute for space science, including the selection and support of 50 outstanding undergraduate science-student attendees.	3,142

State and grant or contract number	Organization, investigator and purpose	Amount
New York—Con.		
NsG-232	Columbia University, W. A. Cassidy Research on quantities and concentrations of extraterrestrial matter through samplings of ocean bottoms.	$25,500
NsG-294	Columbia University, Eugene S. Machlin Conduct materials research investigations using the field ion emission microscope.	20,000
NsG-394	Adelphi College, Donald E. Cunningham Multidisciplinary space-related sciences and technology.	76,920
NsG-445	Columbia University, H. Foley Theoretical and analytical studies of planetary and stellar structure, evolution and dynamical processes; and the applicability of geophysical methods to such studies.	100,000
NsG-471	Cornell University, T. Gold A theoretical and experimental study of gaseous regions in interplanetary space.	11,264
NsG-476	State University of New York, C. U. Lowe An investigation of the synthesis of amino acids and polypeptides in the primitive Earth atmosphere.	87,189
NsG-489	Yeshiva University, Sidney Weinstein Effects of sensory rearrangement, deprivation and isolation on auditory, visual and somesthetic sensation, perception and spatial orientation; including measurement and analysis of thresholds for simple and for complex behavioral patterns.	211,829
NsG-499	New York University, James E. Miller A theoretical investigation of the properties of planetary atmospheres.	5,000
NsG-501	State University of New York, James F. Danielli Studies in cellular theory and molecular mechanisms.	201,787
NASr-172	American Institute of Aeronautics & Astronautics Partial Support of the AIAA Journal.	41,900
NASr-206	Syracuse University, Stephen K. Bailey Social science work concerning (1) management and public policy implications of decisions-making in space and related programs, and (2) prospects for developing interdisciplinary research and training at the graduate level.	123,500
NASr-209	Rice University, B. J. O'Brien Contract for investigations and analyses of particle and light flux in aurorae and air-glow using rocket-borne instrumentation.	200,000
North Carolina:		
NsG-524	North Carolina State College, Ernest A. Ball Growth and morphogenesis of plant tissue in the gravity-free state, for the purpose of refining and verifying an experiment suitable for use in a biosatellite.	27,072
NASr-186	North Carolina, University of, K. M. McIntyre A space science audio visual media workshop which will select, produce, and evaluate audio-visual media and other materials for a space science curriculum for 8th grade instruction in North Carolina schools.	24,853
Ohio:		
NsG-110	Case Institute of Technology, L. A. Schmit, Jr. Research to establish methods of systematic structural synthesis.	22,500
NsG-198	Case Institute of Technology, Osman Mawardi Conduct experimental and theoretical research in plasma dynamics.	3,500
NsG-448	Ohio State University, C. Levis Theoretical and experimental investigations of spacecraft antenna problems in the varied operational environments of far-out-space and atmospheric re-entry, including considerations of immersion in a hot plasma sheath and of omni-directional coverage.	44,830

State and grant or contract number	Organization, investigator and purpose	Amount
Ohio—Con.		
NsG-463	Kent State University, JOHN W. REED Theoretical and experimental studies of the magnetic and molecular properties of selected compounds, using neutron diffraction techniques.	33,462
NsG-544	Case Institute of Technology, L. R. BRAGG Special functions and solution representatives of partial differential equations.	11,940
NASr-12	General Electric Company, H. KIRTCHIK Development of analytical methods for determination of oxygen in potassium metal.	8,000
NASr-187	Ohio State University, HERMAN J. PETERS The development of booklets on guidance in space science and technology for elementary, junior high, and senior high schools.	14,007
Oklahoma:		
NsG-454	Oklahoma State University, JOHN A. WIEBELT Research on a self-temperature regulating spacecraft skin system.	22,184
Pennsylvania:		
NsG-84	Temple University, J. LLOYD BOHN The production of hypervelocity particles of small size and to increase the sensitivity of micrometeorite detection techniques.	12,000
NsG-85	Pennsylvania State University, G. F. WISLICENUS Investigation of the performance and flow conditions in the test section of maximum mach number wind tunnels, including studies of temperature.	115,100
NsG-134	Pennsylvania State University, J. NISBET A preliminary investigation of a rocket and separating capsule method of measuring electron density in the ionosphere.	131,608
NsG-270	Drexel Institute of Technology, P. C. CHOU Theoretical analysis of the stresses induced into the walls of a liquid filled propellant tank impacted and penetrated by a small hypervelocity particle, including prediction of impact conditions at which catastrophic failure of the tank wall will occur.	8,721
NsG-316	University of Pennsylvania, M. ALTMAN Research in the conversion of various forms of energy by unconventional techniques.	125,000
NsG-325	University of Pennsylvania, J. O'M. BOCKRIS Studies of the fundamental chemistry, properties, and behavior of fuel cells.	99,973
NsG-473	Pennsylvania State University, O. F. TUTTLE A program of research to establish criteria for the recognition of ancient meteorite impact craters whose characteristic surface forms have been obliterated by erosion.	61,563
NsG-497	University of Pennsylvania, WALTER ISARD Historical, and related analysis of local and regional impacts of research and development expenditures.	225,000
NsG-500	University of Pennsylvania, S. SOBIESKI Investigations and analysis of the chromosphere by means of spectrograms from cinematographic observations taken during the eclipse of July 20, 1963.	3,000
NsG-506	Combustion Institute, Bernard Lewis Partial support of the Tenth Symposium (International) on Combustion.	25,000
NASr-191	University of Pennsylvania, PAUL S. BALAS Support of the Power Information Center at the University of Pennsylvania.	182,291
NASr-194	American Institute for Research, ROBERT M. GAGNE A study of human factors information requirements relevant to long-term space system development.	21,935

State and grant or contract number	Organization, investigator and purpose	Amount
Pennsylvania—Con.		
R-100	U.S. Navy—Naval Air Engineering Center G. L. Sanwall. Development of full-scale design, fabrication, and test liaison for jet engine noise suppression nozzles.	$88,570
R-105	U.S. Navy—Naval Air Engineering Center. Turbine disk burst protection study.	23,500
NsG-(F)-13	University of Pittsburgh. Construction of a building housing the laboratories for a space research and coordination center on the campus of the University of Pittsburgh.	1,500,000
Rhode Island:		
NsG-418	Brown University, J. Toma, H. Farnsworth. Experimental investigations in epitaxial growth of crystalline layers.	35,000
NsG-488	Brown University, D. C. Drucker. Theoretical analysis of the fragmenting tube energy absorption process.	15,000
NsG-509	Brown University, R. S. Rivlin. Support of a symposium on biorheology to be held in conjunction with the Fourth International Congress on Rheology.	5,000
Texas:		
NsG-263	University of Texas, Matsen and Scherr. Quantum mechanical calculations and studies on atomic systems of astrophysical interest.	102,744
NsG-491	University of Houston. Partial support of a symposium on fluid mechanics, heat transfer, and material behavior applied to problems related to bearings, lubrication, and rotor dynamics.	5,000
NsG-523	University of Texas, P. O'B. Montgomery. Influence of zero gravity on isolated human cells, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	14,935
NsG-548	Arlington State College, Garvin McCain. Study of the effects of protective filters and lenses on color judgment.	13,287
NsG-551	University of Texas, B. D. Tapley. A studyof theory and analysis of low-thrust guidance problems in deterministic linear control.	21,138
NsG-560	Texas Womans University, Pauline Mack. An Investigation of bone density changes in various sites of the skeletal anatomy of primates, for the purpose of defining and verifying an experiment suitable for use in a biosatellite.	16,223
NASr-94(05)	Southwest Research Institute, T. Wan. Investigation of the nonlinear dynamic response of continuous systems.	31,454
NASr-198	Graduate Research Center of the Southwest, K. G. McCraken. To develop and evaluate techniques and instrumentation for the measurement of cosmic radiation anisotrophies.	131,140
NASr-209	Rice University, B. J. O'Brien. Contract for investigations and analyses of particle and light flux in aurorae and air-glow using rocket-borne instrumentation.	200,000
Utah:		
NsG-557	University of Utah, R. Grant Athay. Study of solar-physics experiments involving electromagnetic radiation, by solar probes within 0.1 astronomical units of the sun.	14,000
NASw-105	University of Utah, C. W. Taylor. Predicting success in scientific laboratories from biographical information.	11,995

State and grant or contract number	Organization, investigator and purpose	Amount
Virginia:		
NsG-266	Medical College of Virginia Physiological effects of labyrinthine stimulation.	$15,000
NsG-455	University of Virginia, R. Ziock, R. Ritter Theoretical and experimental investigations of particle detection and particle detectors to improve effectiveness, accuracy, and discrimination.	120,000
NsG-480	University of Virginia, L. W. Frederick Problems in astronomy suitable for study by means of manned orbiting observatories, and related instrumentation and operational requirements.	12,443
NsG-567	College of William and Mary, W. M. Jones Multidisciplinary research in space sciences and technology.	400,000
Washington:		
NsG-401	University of Washington, Ballard and Dill Analytical and experimental study, using photoelastic methods, to establish a stress analysis of a viscoelastic model subjected to transient temperature and time-dependent loading.	8,000
NsG-484	University of Washington, T. S. Shelvin Multidisciplinary research activity in the materials sciences with emphasis on investigations on inorganic nonmetallic (ceramic) materials.	400,000
NsG-532	University of Washington, A. S. Kobayashi An investigation of stresses and strains at crack tips in thin, infinite plates, subjected to various loadings.	17,157
NASr-207	Washington State University To initiate and develop a specific space-related teaching syllabus and supplementary materials for in-service mathematics instruction for elementary teachers.	5,175
West Virginia:		
NsG-533	West Virginia University, J. F. Golay Space-related studies in the physical, life, and engineering sciences.	100,000
Wisconsin:		
NsG-275	University of Wisconsin, J. O. Hirschfelder Conduct program of research in theoretical chemistry, particularly in molecular quantum and statistical mechanics, directed toward determination of the physical and chemical properties of materials relation of these macroscopic properties to properties of individual molecules, and determination of structure and properties of the ind. molecules.	370,000
NsG-(F)-11	University of Wisconsin, J. O. Hirschfelder Construction of additional laboratory research facilities for the Theoretical Chemistry Institute.	442,760
Foreign:		
NsG-219	University of Canterbury, C. Ellyett Radar studies of the occurrence and behavior of meteors in the Southern Hemisphere.	9,000
NsG-478	University of Iceland, Throbjorn Sigurgeirsson Partial support for a continuing determination and recordation of geomagnetic field intensity.	2,000
NASr-208	Commonwealth Scientific & Industrial Res. Org., R. G. Giovanelli The development and construction of one set of equipment basic to a cinematographic study of solar magnetic fields.	97,000

Appendix N NASA International Activities Summary (Cumulative to Dec. 31, 1963)

Location	Cooperative projects							Operations support (tracking and data acquisition networks)						Personnel exchanges			
				Ground-based projects for—													
	Satellites	Experiments on NASA satellites	Sounding rockets	Meteorological satellites	Communications satellites [1]	Ionosphere beacon satellites	Ionosphere sounding satellites	Scientific satellite	Manned flight	Deep space	Optical	Moonwatch	Data acquisition	Resident associates	International fellowships	Training	Visitors
Argentina			X	X		X	X				X	X			X	X	X
Australia			X	X		X		X	X	X	X	X		X		X	X
Austria				X		X						X			X		X
Belgium				X			X							X	X		X
Bermuda									X								
Bolivia							X										X
Brasil				X	X	X						X	X	X		X	X
Burma				X													
Canada	X		X	X	X	X		X				X		X		X	X
Canton Island (U.S.-U.K.)									X								
Ceylon														X			X
Chad				X													
Chile						X	X	X				X				X	X
China, Republic of				X								X		X	X		X
Colombia				X			X							X			X
Costa Rica				X													
Czechoslovakia				X													X
Denmark			X		X		X					X		X			X
Ecuador								X								X	X
El Salvador				X													
France	X	X	X	X	X	X	X					X		X	X	X	X
Germany, Federal Republic of				X	X	X	X					X	X	X	X		X
Ghana						X											
Greece						X						X		X			X
Hong Kong				X													
Hungary				X													
Iceland				X													X
India			X	X		X					X	X	X	X		X	X
Indonesia				X													X
Iran											X			X			X
Iraq				X													

See footnotes at end of table.

Location	Cooperative projects							Operations support (tracking and data acquisition networks)						Personnel exchanges			
				Ground-based projects for—													
	Satellites	Experiments on NASA satellites	Sounding rockets	Meteorological satellites	Communications satellites [1]	Ionosphere beacon satellites	Ionosphere sounding satellites	Scientific satellite	Manned flight	Deep space	Optical	Moonwatch	Data acquisition	Resident associates	International fellowships	Training	Visitors
Ireland				X													X
Israel												X		X			X
Italy	X		X		X	X						X		X		X	X
Jamaica				X		X	X										
Japan			X	X	X	X					X	X	X	X	X	X	X
Kenya				X		X											
Korea														X			X
Malagasy								X									
Mauritius				X													
Mexico									X			X			X		X
Mozambique				X													
Netherlands				X			X				X	X		X	X		X
New Zealand			X	X		X						X		X			X
Nigeria						X			X								X
Norway			X	X	X	X										X	X
Pakistan			X									X		X	X	X	X
Peru							X	X			X	X				X	X
Philippines												X					X
Poland				X													X
Portugal				X								X					X
Rhodesia/Nyasaland, Federation of				X								X					X
Senegal				X													
South Africa				X				X		X	X	X				X	X
Spain						X	X		X		X				X		X
Sudan				X		X											X
Sweden			X		X	X	X							X	X	X	X
Switzerland				X		X								X			X
Tanganyika												X					X
Thailand				X													X
Turkey														X			X
Uganda												X					
United Arab Republic				X													X
United Kingdom	X	X		X	X	X	X	X				X		X		X	X
Uruguay												X		X			X
U.S.S.R.	X																X
Zanzibar									X								X

ESRO [3]																X	X
Total	5	2	12	41	10	23	14	8	7	2	9	28	4	25	12	17	[2] 76

[1] Denmark, Norway, and Sweden are participating jointly as the Scandinavian Committee for Satellite Telecommunication.

[2] The following, included in the total, participated only in the visitor program; Afghanistan, British Guiana, Cambodia, Cameroons, Dahomey, Dominican Republic, Dubai, Ethiopia, Finland, Guatemala, Honduras, Lebanon, Luxembourg, Malaysia, Morocco, Paraguay, Saudi Arabia, Sierra Leone, Somalia, South Viet-Nam, Syria, Trinidad, Venezuela, Yugoslavia, European Launcher Development Organisation (ELDO).

[3] European Preparatory Commission for Space Research (ESRO). ESRO-sponsored international fellows are indicated under the countries they represent.